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Monte Carlo Computer War Gaming (U)

A Feasibility Study

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Operating Under Contract with the

DEPARTMENT OF THE ARMY

WORKING PAPER

This is a working paper of members of the technical staff of the Tactics Division concerned with ORO Study 15.1, but the calculations were completed in Project ARMOR under the previous ORO organization.

It is the objective of Study 15.1 to develop and apply analytical techniques for the comparison of tactics, organization, and weapons systems within the context of a realistic two-sided battle situation. This paper, "Monte Carlo Computer War Gaming: A Feasibility Study," represents a preliminary investigation of a technique for simulating the effects of fire and maneuver in a small-unit action. The findings and analysis are subject to revision as may be required by new facts or by modification of basic assumptions. Comments and criticism of the contents are invited. Remarks should be addressed to:

The Director
Operations Research Office
The Johns Hopkins University
7100 Connecticut Avenue
Chevy Chase 15, Maryland

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TACTICS DIVISION
ARMOR & TACSPIEL GROUPS
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Monte Carlo
Computer War Gaming (U)
A Feasibility Study

by

R. E. Zimmerman
Operations Research Office

with Computations by

G. Cramer
Earl Joseph
Engineering Research Associates

OPERATIONS RESEARCH OFFICE
The Johns Hopkins University Chevy Chase, Maryland

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FOREWORD

This is the first of one series of memoranda to be prepared by the Tacspiel Group, Tactics Division, dealing with the TO&E of small units. It describes the basic features of a war-gaming technique which, when fully developed, is expected to contribute to the design of improved TO&Es.

The memorandum is published to acquaint the Army agencies responsible for research and combat developments with the nature of a specialized form of a war game. It is hoped that this will facilitate a critical review of the technique itself as well as contribute to an understanding of its strengths and weaknesses and the nature of the data required for its use.

The immediate area of application of this war-gaming approach will be to assess in relative terms the performance of untried proposals for new small-unit TO&Es in a realistic two-sided combat action. It should aid the timely identification of proposals deserving no further attention and promising ideas that merit more thorough (and expensive) study.

As will be evident from the study, use of a war-gaming technique, like any other technique, imposes the most severe requirements on the analyst in providing for the necessary comprehensiveness and realism of each phase in the analysis. The ultimate source of that comprehensiveness and realism must be experienced members of the combat arms whose judgment is essential to identify relevant battle factors as well as in the design and conduct of field experiments, maneuvers, and (in a limited sense) CPXs testing promising organizations.

Since the memorandum discusses only a technique of analysis, no formal recommendations for DA action are offered.

ACKNOWLEDGMENTS

The writer gratefully acknowledges the inspiration of G. Gamow (ORO consultant), who first proposed the essential features of this methodology,[1] and W. W. Nicholas, who aided greatly in the formulation of the principles applied in these calculations and also strongly supported the detailed study portions of the research that he supervised as chairman of Project ARMOR; the work of G. Cramer and E. Joseph of Engineering Research Associates, who, while under subcontract to ORO, not only contributed their special technical and mathematical skills in applying the ERA 1101 computer to the calculation of these battles, but also aided in the development of the special computing techniques used; and the help of the many ORO staff members and consultants who contributed data, advice, and encouragement.

Special mention should be made of N. M. Smith (ORO), who led the early discussions that produced the guidelines applying to this study; S. Ulam of Los Alamos Scientific Laboratory (ORO consultant), who contributed basic and original thinking on Monte Carlo techniques; Col Billingslea, who supplied authoritative advice and proposals on the tactical aspects of the trail combat action; V. V. McRae and M. C. Grabau, who kindly permitted the use of a very large quantity of original and unpublished tentative performance data for the armored vehicles; G. J. Blakemore, Jr, who supplied certain of the statistical computations; and J. Federico, who prepared certain tabulated data.

The writer is especially grateful to V. V. McRae for his valuable criticism of several drafts of the memorandum. However, the writer alone is responsible for all errors of expression and content.

CONTENTS

CONTENTS (CONTINUED)

PROBLEM

To develop and test the feasibility of a high-speed computational system permitting the simulation of small-unit combat actions in detail in order to improve the numerical evaluation of proposed new weapons, weapons systems, and tactical doctrines.

FACTS

The rate at which unproved weapons of radical or unconventional nature are becoming available to our military forces is increasing tremendously, compounding the difficulty of evaluating new weapons and weapons systems in the absence of actual combat. Some of these weapons may strongly influence the organization and tactical doctrine of the military forces. Thus the effectiveness of all weapons, even those already tested in combat, may be altered. To be adequate, analysis of weapons must be made in the context of the weapons system containing them. Proving-ground data, although necessary, are not enough; yet full field tests of all proposed weapons systems are prohibitively expensive.

There is, therefore, a requirement for a computational technique capable of simulating the operation of a weapons system, and economically screening large numbers of such proposed TO&Es, eliminating quickly impractical proposals and clarifying elements of strength and weaknesses in promising ones.

Conventional mathematical analysis has not yielded a satisfactory or convincing simulation of an entire combat action. There is a widespread belief that this is due in part to the oversimplification required in practice before the operation of a complex system can be reduced to a set of equations.

Recently a technique yielding approximate solutions to problems involving multiple probabilities has come into use. This technique, called "Monte Carlo," has been applied successfully by mathematicians to important problems that had been "unsolvable" owing to the length of time required when using conventional techniques. The system permits a large electronic computer to be employed to carry out the calculations.

Large electronic computers are now available that, in addition to their well-known ability to solve arithmetic problems at great speed, have also a capability for solving "logical" problems rapidly. That is, they can be caused to determine the logical consequences of a given set of facts and/or assumptions.

SUMMARY

DISCUSSION

Tests of new weapons or weapons systems require that proper account be taken of the important battle factors, including terrain, weather, doctrine, enemy strength, troop formations, mobility, human factors, and supporting weapons. Traditionally the world's military establishments have used the war game—or map exercise—as one means of incorporating all these battle factors, and more, into an analysis of the strengths and weaknesses of an existing or proposed TO&E. At the same time attempts to simulate a complete military operation using conventional mathematical techniques have been only partly successful, owing to the multitudinous and interdependent battle factors. Basically this appears to result from the enormous lengths of time required for the complete solution of sufficiently general equations involving the necessary number of variables, even using the most modern computing machinery. It is also true that the merely conceptual task of translating complete military operations into the special forms required for conventional analysis offers formidable difficulties.

The computational system described is in the form of a very detailed two-sided war game but avoids the troublesome mathematical systems previously applied.

Battle Factors

Ten basic factors that may be used in simulation of battle are proposed. For each weapon or unit there are six physical performance characteristics: (1) kill probability; (2) rate of fire (includes logistics); (3) probability of seeing enemy; (4) communication probabilities; (5) mobility (includes mechanical reliability, weather effects); and (6) human factors influencing or limiting the physical capabilities of a weapon. Following these are (7) physical terrain features of the battlefield, in terms of their influence on the first six factors, and (8) the missions of the opposing forces, particularly their terrain objectives. The actual and estimated enemy situation influences the latter factor. The particular principles of tactical doctrine selected to govern the way in which the first eight are to be combined are the bases for (9) doctrine for selecting targets (includes support-fire plan), and (10) doctrine for properly relating the scheme of maneuver to the weapons, the battlefield and mission. This list of variables can be ~~integrated~~ interpreted as including, directly or indirectly, all the information contained in a complete operations order.

The Monte Carlo computing techniques applied to the simulation of battle provide a capability for simulating in detail the battle factors deemed essential, in a conceptually simple manner and within reasonable time limits, but at the expense of complete mathematical accuracy. Thus the Monte Carlo calculations may be considered to provide feasible approximations to (time-wise) infeasible mathematical calculations.

Trial Combat Action

One hypothetical combat operation, consistent with the statement of the problem, serves to aid in the refinement of the model of battle and to test the computational technique. The combat action selected was formulated with the aid of knowledgeable Army officers and civilian technicians. It is patterned after the "Reinforced Tank Company in the Attack" problem performed frequently at the Armored Center, Ft Knox, to illustrate armored small-unit tactics. The attacking forces include a medium tank company, three squads of infantry mounted in personnel carriers, with a battery of 4.2-in. mortars in support. The defenders are assumed to have a company of 10 medium tanks, a company of 5 SP guns and 9 squads of dismounted infantry.

The action is put in the context of an over-all tactical situation and takes place on a piece of terrain patterned closely after an area a little over a mile square in Bavaria, 30 miles north of Würzburg. The major terrain features of this area are similar to those in the area at Ft Knox where the attack problem is demonstrated.

As the first step in refining the model of battle, the combat action is broken down into its essential elements of fire and maneuver. A precise statement of the calculations the computer must perform in order to simulate the actions of fire and maneuver is formulated.

Stated briefly, these fundamental actions of the separate combat elements are reduced to (a) a decision to move from one small 100-m by 100-m square, which is its present position, to a selected neighboring square, taking proper account of the factors of terrain and combat that must influence the selection; and (b) a decision to deliver a single unit of fire against a selected enemy target in accordance with the terrain factors and combat situation, which must influence the selection of a target and the effectiveness of the unit of fire. The majority of the calculations involve probabilities in a natural and necessary way. Hence any single battle calculation can have any one of a large number of possible results. Thus more than one battle calculation must be carried out to determine the average, or typical result.

These two types of fundamental activities by the combat elements in the battle are properly ordered in time by the computer; i.e., are caused to be performed in a sequence that is militarily sensible and at a rate consistent with the capabilities of the weapon and weapon crew.

Statistical Analysis

The results of 114 trial battles are analyzed to determine the nature and statistical accuracy of conclusions that can be derived from a short series of battle calculations.

The fact that chance plays an important part in the calculations raises certain statistical questions that must be investigated, and the trial battle results provide useful answers to these questions. Essentially, one question is

SUMMARY

"How many times must a particular battle be repeated to give an acceptable measure of the 'average' outcome of the battle?" Related to the answer to this question is the spread in the results of a given battle; i.e., the likelihood with which "nonaverage" or exceptional outcomes of the battle occur. The study shows that 50 repetitions, or less, of the computer battle in its present form are sufficient to determine the "average" outcome with acceptable accuracy (about ± 10 percent in the average number of casualties) and shows that the spread of the battle results is fairly measured by the same number of repetitions.*

This first group of test battles is also applied to a test of the ultimate mission of battle simulation, the comparison of effectiveness† of two weapon designs. For this purpose 50 additional battle calculations were obtained for the case where the medium tanks of the assaulting force were replaced by a set of hypothetical tanks with (a) lower kill probability of its gun against the enemy armor, (b) an increased rate of (effective) fire, (c) higher vulnerability to the enemy weapons, and (d) an increased mobility (speed of movement). The change in the numbers that specify the performance of (a) and (c) above follows roughly the difference between M48 medium tanks and M41 light tanks. The changes made under (b) and (d) were hypothetical. Therefore the results of the trial battles computed in this feasibility study cannot be taken in any sense as a comparison of the effectiveness of the M48 medium tanks with the M41 tank. However, the comparison made is a concrete illustration of the area of application of battle simulation. Such a comparison can be made as soon as refined battle codes are devised and acceptable performance data are available.

An additional 14 battles were computed for the case where hypothetical "heavy" tanks replaced the mediums. The performance data for these tanks followed roughly, but only in part, tentative performance data for the T43 tank supplied by the staff of the ARMOR Group.

In both cases, the modification in the performance characteristics of the tanks caused a major variation in the outcome of the "average" battle, which was measurable with useful accuracy and gave rise to a spread of results not so wide as to make predictions impossible.

Application of Model of Battle

With the test-battle code as a base line, the flexibility of the model of battle is discussed and a refined model of battle is developed, which is feasible on computers now available and, it is believed, possesses sufficient detail and realism to permit its immediate application to the solution of real and pressing problems relating to the TO&E of small combat units. Formulation of such a detailed code need take no more than 6 months, once agreement has been reached on the type of combat to be investigated.

*The evidence tends to support the possibility of a much reduced number of repetitions being sufficient in many cases.

†"Effectiveness" is used throughout to refer to the ability of a weapon to accomplish its mission. This is a necessary step before determining the more meaningful and basic "effectiveness per unit cost" of the weapon.

It builds directly on the lessons learned from this feasibility study and takes into account such refinements as appear necessary for the production of an immediately usable computer battle code. In particular the necessary flexibility in the tactical doctrine governing the actions of the combat units is provided for. The command-control structure of subordinate units is an integral part of the proposed code and permits inclusion of the important command-control problems in a realistic fashion, including modification of the mission and of the tactical means used in the execution of the mission during the battle calculations. Since such command decisions are made on the basis of the commander's knowledge at the time, the operation and effectiveness of the commander's data-gathering system, including his radio net, are a part of the proposed computations.

Although this model of battle was developed expressly to simulate small-unit combat actions, the model is not necessarily restricted to that use. The components of the model—such as combat elements, grid squares, terrain objectives, and kill probabilities per unit of time—can also be applied to large-scale combat operations, provided reasonable estimates of the corresponding performance characteristics of entire platoons, companies, or battalions are available.

CONCLUSIONS

1. The Monte Carlo technique enables a very large number of battle factors to be introduced into a feasible analysis of the performance of alternative weapons and weapons systems. The number of battle factors is sufficient to warrant designation of the computing system as a "battle simulator."

2. The technique permits direct participation of nonmathematical personnel—most importantly, officers with extensive combat experience—at every significant step of the design and criticism of controlled, scientific war gaming.

3. The battle factors used are sufficiently comprehensive and basic to permit great flexibility in the manner of their combination into various combat situations involving a variety of weapons and at any echelon for which the performance characteristics of the weapons systems may be specified.

MONTE CARLO COMPUTER WAR GAMING
A FEASIBILITY STUDY

INTRODUCTION

PROBLEM

The most pressing military problems currently requiring analysis result from the apparent necessity of countering the Soviet military threat with unproved weapons. Tactical and organizational innovations that may appear desirable to exploit such new weapons fully may cause, throughout the organization, unexpected chain reactions that could nullify the expected improvements. As the expected tempo of battle is stepped up, the command-control-communication system becomes more critical. As the weapons themselves become more complex the nature and degree of logistical support and training required acquire an increasingly critical bearing on the selection of the best weapon system.

The potential of the existing and predicted technology not only produces very complex weapons systems but produces them in substantial variety. There is almost an "embarrassment of riches" among the competing proposals for new weapons systems. It is clearly out of the question to subject every one of the proposed TO&Es to the heavy expense of full-scale field tests. Yet many of the proposals involve such radical and untried weapon systems and tactical innovations that neither experience nor conventional theoretical analysis appears capable of adequately screening them for merit.

The methods of screening numerous proposed weapon systems is the problem area to which this memorandum is addressed.

WAR GAMING

The use of war games by the world's military establishments to aid in planning and training has a long history.[2] Map exercises and war games used as a part of the war planning process are not usually expected to predict accurately the outcome of some future battle or war. Rather the process is useful in pointing up elements of strength and weakness in existing troop formations, weapon stocks, and/or logistical operations. Such apparent strengths and weaknesses can then be made the subject of more detailed study by the responsible officers and their staffs to determine if the apparent strengths and weaknesses are real and, if so, to determine what action is indicated to exploit more fully the strong points and to remedy the weak points.

The results of such war games are not ordinarily accepted in an absolute sense. Rather they are used as a basis of comparison with the results of war gaming an alternative action. This characteristic of war gaming is common to

all theoretical computations; i.e., the relative (in the nonmathematical sense) standing of two proposed weapon systems is apt to be a great deal more meaningful than the absolute effectiveness values computed.

The special contribution of the war game to planning is, of course, the natural way in which the influence of one phase of the operation on another phase may be shown. Traditionally war gaming in the form of map studies (and to a much lesser extent, command post exercises) has required the continuous participation of experienced senior officers to provide authoritative umpire decisions at crucial times during the game. Attempts to condense such authoritative judgments to a limited set of rules have in the past met with a general lack of success. Consequently many personnel engaged in the scientific analysis of military problems have experienced great difficulty allowing for the influence of necessary battle factors.

Clearly the utilization of war games to provide for a more realistic assessment of the capabilities of men-weapon teams in scientific analysis requires that the judgment of experienced officers be a part of the analysis. But also such judgments should be in a form amenable to the special techniques of scientific analysis.

The technical analysis of weapon effectiveness has always depended on the availability of performance data such as kill probability and range. Such performance data can frequently be determined on the proving ground. However, proving-ground data do not always take adequate account of combat conditions, particularly those involving human factors. For example, the kill probabilities of small-arms fire is known to be significantly less in actual combat than that deduced directly from their performance on the firing range. So long as historical records of the effectiveness of small-arms fire are available, appropriate corrections to the measured performance of a new small arm can be made on the assumption that the new small arm would be used in combat very much like the old one. However, when a new weapon has radically different characteristics from the old, or when the battlefield conditions are radically altered, it becomes unlikely that such an assumption is justified. It then is extremely difficult to estimate in a simple way the necessary corrections for human factors and the influence of other weapons in the combat team.

The war game described in this technical memorandum is especially designed to provide a means so that (a) man-weapon performance data as determined from field experiments and (b) the judgment of experienced officers regarding important human factors may be incorporated in a natural way into theoretical calculations of weapons systems effectiveness.

Naturally no war game or calculation can be used uncritically to predict the future. The results of any analysis in advance of actual combat—whether technical or military—is at best only one of the many factors the commander on the spot must take into account when battle is joined. However, results of technical analysis that have had the benefit of treatment in the more realistic context of a war game should be of material assistance to the responsible officers in the design and testing phase of new weapons systems.

FACTS AND ASSUMPTIONS

This section lists basic facts and assumptions on which this study rests. In general the facts relate to the capabilities of computers and past experience with special mathematical computing techniques such as the Monte Carlo approximation. More numerous are the assumptions adopted (a) to characterize the simulation of battle, (b) the list of battle factors which comprise the simulation, and (c) time considerations limiting the scope of the calculations.

SIMULATION OF BATTLE

The essential features of combat that must be simulated appear to be:

(a) Opposing combat units and their capabilities (battle factors 1 to 6, next section).

(b) A battlefield (battle factor 7).

(c) An over-all mission for both sides (battle factor 8).

(d) The technique or doctrine of fighting to be applied (battle factors 9 and 10).

To have great flexibility and wide areas of application the rules for conducting the war game must permit a variety of choices in each of these four areas. The mission of this study is to demonstrate by example that it is feasible to compose such a set of rules with the necessary flexibility and that modern high-speed computing machinery can be used to conduct any desired portion of the resulting war game.

This memorandum first lists in general terms the physical variables believed to be required to implement the construction of a war game. These physical variables correspond to the first three essential features of combat listed above. They must be defined in a fashion that leaves completely open the fourth factor, i.e., the choice of a technique for applying the available military force toward the accomplishment of the (combat) mission, but at the same time permits straightforward implementation of any desired tactical doctrine.

BATTLE FACTORS

The battle factors (or variables) that were selected as essential for the simulation of fire and maneuver are:

(1) Kill probability per round, burst or salvo, of a particular weapon or crew, vs opposing weapons or crews.

(2) Rates of fire of weapon crews (includes necessary logistic factors).

(3) Probability of seeing enemy (depends strongly on terrain features but includes other combat factors).

(4) Communication system (determines how quickly and accurately combat information known to one battle participant is shared with another).

(5) Mobility (particularly of combat vehicles but including entire combat units where appropriate; includes effects of weather and mechanical reliability of vehicles).

(6) The human factors (which influence performance levels of weapons and weapon systems so far as the identified battle factors are concerned).

(7) Physical terrain features of battlefield (includes influence of weather).

(8) Mission of units (including terrain objectives if necessary).

(9) Priority system (for selecting a target among available enemy units).

(10) Tactical doctrine for maneuver (as it relates movement to terrain features, the mission, and progress of battle).

The first six of these factors are pure performance characteristics of a weapon, or more generally, a weapons system, and constitute the raw material of military force. Each of these six, singly or in combination, call for objective data that may be determined from historical battle accounts, proving-ground experiments, field exercises, and maneuvers or theoretical studies.

The seventh battle factor, physical terrain features of battlefield, represents the point of application of military force. It too is represented by objective performance data, in the sense that a given terrain feature derives its battle significance only from its influence on the performance characteristics of combat units.

The eighth factor is a quantitative statement of the mission of each of the opposing units. For the attacking unit this is conventionally a terrain objective, and for the defending forces the mission is conventionally to frustrate the efforts of the attacker. Clearly other missions may be assigned and, further, the mission may be qualified by self-imposed limitations on acceptable casualty levels, specific time limitations, or similar qualifications. In any event the missions are capable of being precisely and quantitatively described.

The remaining two "factors," however, are something else entirely. They are not intrinsically measurable quantities. Rather they represent the intent of a set of rules, or expression of doctrine, that permits a selective application of the available military force on the battlefield. Without these last two factors there could, of course, be no sensible combination of the first six battle factors (force) with the seventh (terrain). Indeed the ultimate purpose of this war-gaming technique requires the quantification of tactical doctrine in terms of the performance characteristics of the opposing weapon systems and within the framework of specified missions on specified terrain.

Therefore a method of computation that allows the influence of approximate forms of the battle factors to be made a natural part of battle simulation must be described. The study does not concern itself with determining accurately the numerical values of the factors. However, all the factors used are so defined that they may be determined by field experiments to a useful accuracy. In case the weapons under consideration are not yet in existence the simulator would be used to determine the importance of a proposed performance level of a selected battle factor (e.g., mobility), so as to determine how much relative emphasis should be placed on improving competing performance levels, e.g., armor protection.

Concerning these battle factors, three assumptions basic to the development of the model of battle here presented are:

(a) Simulation of battle requires that each of the 10 battle factors appear explicitly in the model of battle; this list of battle factors is sufficiently comprehensive to warrant classifying the resulting model of battle a "battle simulator."

(b) The numerical values of these battle factors are too imperfectly known at this time to justify applying the model of battle to any but the lowest echelons —the individual tanks in a tank company and the individual squads in an infantry company.

(c) The battle factors are so numerous, and their interdependence so complex, that completely accurate solutions cannot be found by conventional mathematical means.

It is obvious that only time will tell whether these three assumptions are completely justified. However, one of the purposes of the material presented in this memorandum is to demonstrate, so far as is practicable, the plausibility of these assumptions.

To ensure clarity, the 10 factors are further refined in the context of a concrete example—a sample combat action. It is desirable to do this—not only because it is difficult to discuss combat in a tactical vacuum but also because the special strength of the Monte Carlo method is best shown by an actual application of the technique.

However, after the factors have been refined in terms of the example, their flexibility and generality is discussed.

Before developing the trial combat action the remaining facts and assumptions must be reviewed.

THE MONTE CARLO APPROXIMATION

A basic assumption is that, to simulate battle successfully, the battle factors used must refer directly to the individual participants in a combat action—at least so far as the major combat elements are concerned. For example, tanks were selected as the combat element to be emphasized in this feasibility study. Thus it is assumed to be necessary to treat the tanks individually. That is, their movement, firing, and other important actions must be treated as distinct actions —not averaged out over a platoon or other tactical unit.

This assumption appears attractive for at least three reasons: First, the physical characteristics of weapons are (usually) best determined on an individual basis and are (usually) the most accurate information available. The results of calculations starting from such data are apt to be more believable than calculations starting from less well-known data.

Second, the proposed methodology will be the more flexible the more readily weapons and equipment are added, altered, or removed from the weapon systems. It is more convenient to do this when the battle model includes the weapons and their characteristics explicitly than when weapons and equipment must be combined in some average way before insertion into the model of battle.

Finally, one of the primary purposes of constructing this new model is to render the interactions between distinct weapons susceptible to calculation.

Thus to the extent that these interactions are averaged out prior to insertion into the model they are not subject to analysis, and part of the purpose of the methodology would be frustrated.

To carry out such extensive calculations requires that the most powerful and rapid computing facilities be employed. The use of modern high-speed computers is therefore a necessity.

Some compromise is required in this regard. A computer does not have an infinite capacity to treat all weapons and other equipment separately. The necessary compromises grow out of specific limitations of the computing machinery. They are discussed in later sections.

When describing separate actions of an individual combat unit, e.g., a tank, it appears inescapable that probabilistic notions are required. Thus with a given round a tank will either hit an enemy tank or it will fail to do so. The difference between various tanks in this regard can only be in the probability of a hit. Similar though more complex notions apply to the probability of a kill.

Once probabilities are injected into a calculation the outcome of that calculation cannot be a certainty. Thus if a model of battle that assigns probabilities to describe the performance of a weapon is constructed, then a single simulation of any given battle could have any one of a large number of outcomes, according to the play of chance. The difference in effectiveness of competing weapon designs can therefore be measured only by means of the difference in the average outcome of the battle or by similar factors. This is a basic limitation on the use to which this battle simulator may be put. It is a natural one. It is tempting to interpret it as a general inability of humans to know the present in such detail as to be able to predict the future with certainty.

There is every reason to believe that a model of battle including the proposed number of battle factors, and in the great detail required to treat each combat element distinctly, would require a prohibitive cost in time and/or money for its complete accurate solution using conventional mathematical techniques.[3]

However, a technique for providing approximate solutions to such complicated problems in much less time is known and has been in use by applied mathematicians for some time, particularly since 1943.[3] This approximate method of problem solution is called the "Monte Carlo technique" and is based on the everyday concept of probabilities and the science of statistics. It is therefore particularly useful when the problem to be solved itself involves many complicated probability actions such as kill probabilities and the probability that one combat unit will detect an enemy unit.

A Monte Carlo calculation can be considered as a straightforward substitute for the use of a probability equation. For example, suppose it is desired to determine the probability P that a tank will be knocked out by either the first or second shot from an antitank gun, assumed to possess a constant kill probability per round of $p = \frac{1}{2}$. The correct answer is given by the simple equation

$$P = p + (1 - p)\, p = 2p - p^2 = 1 - 0.25 = 0.75$$

If the Monte Carlo method is used in place of the equation, the value of P could be found by simulating each round of the antitank gun by the flip of a coin, calling a hit when a head comes up (probability of a head is $\frac{1}{2}$), a miss for the tail.

Any "honest" gambling device displaying the proper "odds" could be used. If a record were kept of the results when the coin was flipped, say 1000 times, then the value of P so determined would almost certainly be very nearly the correct answer, 0.75.* Clearly the Monte Carlo method would be a poor substitute for the equation in the simple problem above. However, some systems are so extremely complicated that it is all but impossible to write down and solve the required equations. In many such cases the Monte Carlo technique has proved an effective means for approximating their solution,[3] particularly since high-speed electronic computers can be used to simulate the flip of a coin (or other mechanical actions) involving the play of chance.

There is a second important reason for investigating a methodology using Monte Carlo calculations. This memorandum demonstrates that the Monte Carlo system of calculation permits a very close and detailed correlation to be maintained between each separate operation in the real battle and that part of the battle simulation corresponding to it. Perhaps this is due to the nature of the human thought and decision processes necessarily included in a battle simulator. Human reasoning appears to depend more on a system of "logical computation" than on an arithmetic or mathematical system, and the model of battle described in this memorandum makes important use of such "logical" computations.

Still, a compromise between the use of Monte Carlo operations and conventional mathematics is frequently desirable. Such compromises usually result from the limited capacity of the computing machinery. They are discussed as the need arises.

TIME LIMITATIONS

Use of the Monte Carlo technique results in the necessity of repeating the battle for every distinct set of initial conditions (such as choice of weapons, terrain, and mission) a number of times sufficient to determine the average battle outcome and other related factors. The number of repetitions required depends on the accuracy with which it is desired that the average shall be determined, and on the spread of the results. The science of statistics applies to this determination. A necessary part of this feasibility study is therefore the series of trial calculations described in later sections, which indicates the spread of battle outcomes to be expected when this model of battle is used in analysis and permits determination of the approximate number of battle repetitions required.†

The accuracy with which the average battle outcome must be determined is dependent in part on how similar are the battle results when two alternative courses of action are compared. For example, it may be desired to determine which of two proposed tank designs is more effective. In this case the battle must be repeated a number of times, increasing as the more nearly identical are the effectiveness values of the competing tank designs. That is, a few repetitions may be sufficient to demonstrate an overwhelming superiority of one

*Statistically there would be only about 1 chance in 1000 that the value of P calculated by the above procedure would fall outside the interval 0.70 to 0.80, i.e., be in error by more than ± 7 percent.

†No attempt is made here to investigate possible application of certain refined statistical theories that may further reduce the required number of battle repetitions.

tank over another, but a much larger number of repetitions is necessary if it is required to demonstrate a marginal superiority of one tank over another.

It is therefore important to compute a second series of trial battles so as to indicate the sensitivity of the battle results to a significant variation in the performance characteristics of the tanks involved.

From the preceding discussion it is clear that a major restriction on the scope of the combat action to be simulated is the length of time that can be allowed for the computer to simulate a single battle. This does not depend on details of the design of the battle simulation. It depends only on the way in which the battle simulator may be applied to the solution of military problems and on the decision to use Monte Carlo calculations.

To establish an approximate limit on the length of time to be allowed the computer, suppose that it is desired to investigate the relative desirability of different calibers of tank guns when mounted on the same basic tank chassis. Thus factors of mobility and armor protection may have been fixed at some value, and within wide limits the caliber of the main gun may be varied. As the caliber of the main gun is varied, certain related factors must also change. Thus the base load of ammunition generally decreases as the caliber of the weapon increases if, for all calibers, the best high-pressure designs are used. Also the effective rate of fire may decrease as the rounds become heavier and more cumbersome to handle. The diameter of the turret ring may also change and, with it, certain proportions of the tank design.

A straightforward application of a battle simulator to this design problem would involve simulating the battle between a fixed enemy force in a fixed tactical situation while varying the caliber of the main tank gun. If a measure of the effectiveness of a tank were agreed on,* the caliber of tank gun yielding the best performance in this regard could be selected. Simulating the battles resulting from 10 different choices of main gun caliber might be sufficient to identify (by interpolation) the gun caliber yielding the best performance in the particular battle situation selected.

In general the choice of any weapon requires that it perform well in a variety of tactical situations. Thus the performance of each caliber of tank gun needs to be tested in perhaps 10 different tactical contexts. For example, these might include (a) attack of heavily fortified position, (b) exploitation, (c) airborne assault, (d) delaying action, (e) mobile defense, and (f) counterattack to restore a position. This second factor of 10 raises the number of battles requiring simulation to 100. Finally it is necessary to test how critically each of these 100 battle results depends on certain major assumptions, such as the level of training of the crews and the quality of enemy equipment to be expected. Perhaps 10 such assumptions would require some variation, which when multiplied by the factor of 100 already derived indicates that as many as 1000 battles may need to be simulated in the process of a thorough investigation of the main armament of a tank.

This is of course an extremely detailed application of battle simulation. Much of value could be learned with a less extensive analysis. However, if it is

*A simple definition of tank effectiveness has been used by V. McRae and A. Coox in ORO-T-278, "Tank-vs-Tank Combat in Korea." There, tank effectiveness was defined as the *ratio* of the average number of enemy tanks killed by each friendly tank to the average number of friendly tanks killed by each enemy tank. Other definitions of effectiveness have been proposed, including cost effectiveness, which includes the elements of production and logistical costs.

to be possible to carry out such a detailed program in 6 months to a year, so as to permit timely solutions, then each battle simulation can consume no more than the order of 1 hr.*

The limitation on a single battle calculation is therefore in the order of a few minutes since, as was discussed above, each battle simulation requires a number of repetitions of a single battle so that the average battle results may be determined. Thus if on the average 30 repetitions were sufficient to determine the average battle result of a single combat situation, then each separate battle can consume but 2 min of computer time so as to provide one average battle result each hour.

It must be emphasized that the example discussed above is not the only way in which the methodology may be applied to analysis. It represents what is thought to be the most extreme case among possible applications and therefore results in the most stringent limitations on the time that should be available to the computer.

Since the computing machinery that may be used in the application of the proposed methodology is at least 10 times as fast as the ERA 1101 computer used in this feasibility study, a time limit 10 times larger than that calculated above can be used here. Thus the average computer battle on the 1101 computer should be completed within 20 min. Since the basic assumption was to treat the battle participants and equipment in as much detail as is feasible, no lesser time is considered for purposes of this feasibility study.

CAPABILITIES OF ELECTRONIC COMPUTERS

Certain facts and assumptions previously described strongly influence the methodology. The nature of the proposed methodology also depends critically on the capabilities of the computer. A discussion of only the most essential features of a computer follows.

Nature of Computers in General

The essential difference between a desk calculation machine and the electronic computers used for computer battles is the "automatic" nature of the latter. That is, an electronic computer can not only add, subtract, multiply, and divide but can also be instructed to perform a long series of such operations in any desired sequence with no further attention required from the human operators. It can be instructed to carry out such an extensive number of mathematical operations that a special means—a "flow diagram"—is used throughout this study wherever it is necessary to show the order in which these mathematical operations are performed by the computer. The general character of a flow diagram is illustrated by Fig. 1. Each block indicates some simple calculations that the computer must carry out. The arrow or arrows leading from a box then indicate the next operation. By following along the arrows in a flow diagram every step of the computations can be traced out. In principle such a flow diagram relates only to the logical structure of the computation itself and not at all to the particular computer for which it is designed. In practice, however, the particular way in which the over-all problem is broken down into simpler parts will depend on the special characteristics of the particular computer.

*1000 hr = 25 40-hr weeks or about 6 months of computer time.

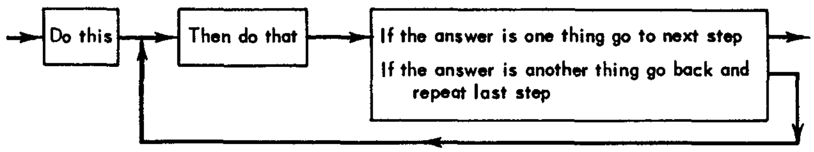


Fig. 1—Example of a Flow Diagram

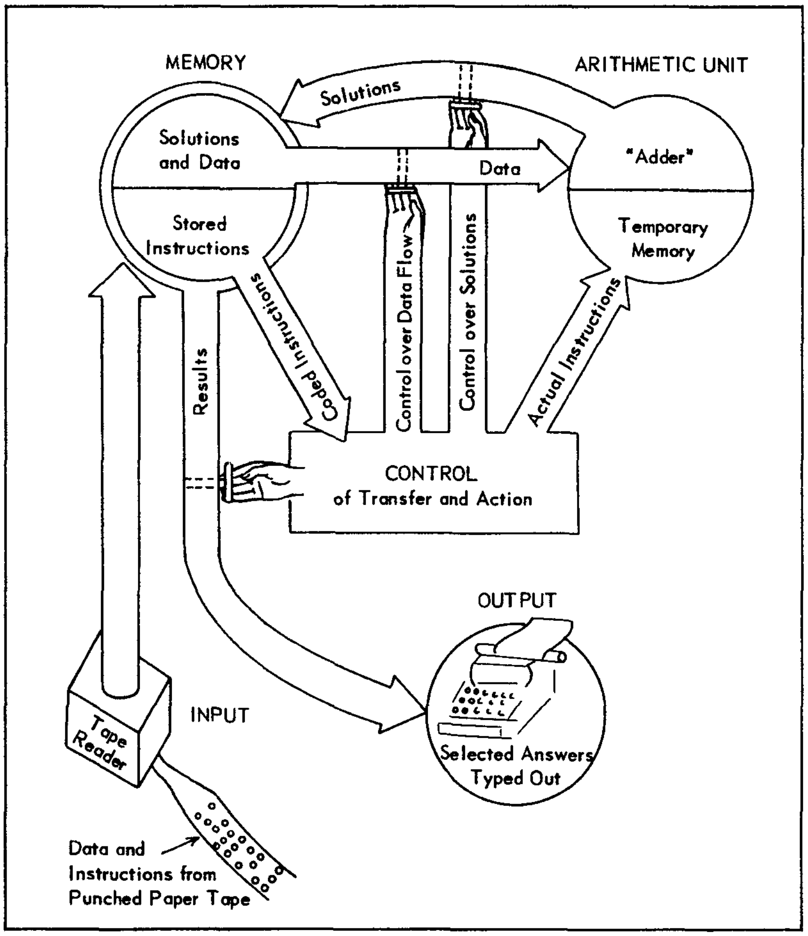


Fig. 2—Schematic Diagram of Typical Electronic Computer

The Computer. The computer itself can be described generally without detailed reference to its actual physical structure. Thus all general-purpose electronic computers can be considered as composed of four functional subgroups. These are:

(a) The arithmetic units (those in which adding, subtracting, etc., is actually carried out).

(b) The memory units (those in which numbers are retained before, during, and after use).

(c) The control units (the source of the instructions telling the arithmetic units what to do next, where to get the numbers to be used, and where to store the answers).

(d) The input-output units (the machinery used by the human operator to tell the computer what to do and which numbers to use; and the machinery used by the computer to "tell" the human operator what it has done, and what the answers are).

These functional units are usually, but not necessarily, associated with separate electrical or mechanical units. In the case of the ERA 1101 computer used for this feasibility study, the physical equipment performing the four functions (Fig. 2) are (a) arithmetic unit: about 600 ordinary (radio-type) vacuum tubes; (b) memory unit: a rotating cylinder, covered with a magnetic substance similar to that used on magnetic tape (phonograph) recorders, which records voltage pulses interpreted as numbers and has a capacity of 16,384 seven-digit numbers; (c) control unit: about 400 ordinary (radio-type) vacuum tubes; and (d) input-output unit: input is by paper tape having holes punched in it by a special typewriter; output is by the same type of paper tape and/or a direct connection from the computer to a fast electric typewriter.

The computer can be caused to perform any stated sequence of arithmetic operations (add, subtract, multiply, and divide) and certain special forms of these arithmetic operations, usually called "logical" operations. These are more completely described in App A.

The procedure to be described for making use of the computer in this study has six stages: (a) a sample military engagement is broken down into simple understandable steps, each involving a single elementary action by a small combat unit; (b) each step is translated into an equivalent mathematical or logical operation that the computer can perform; (c) a number code that will cause the computer to carry out all the calculations in the desired order and that includes all the numbers necessary for the calculations is prepared; (d) a punched-hole paper tape of the necessary length is then prepared by typing the number code on a special typewriter; (e) the prepared paper tape is fed into the computer, which then starts its calculations; and (f) selected results of the calculations are caused to be typed out directly onto a special typewriter as they are obtained. At the same time a more detailed record of the calculations is also punched out by the computer on paper tape that can be inspected at a later time.

However, this more detailed account of the calculations cannot be conveniently read directly. The paper tape must be rerun through the computer while the computer reinterprets what had been punched out originally on the tape. In so doing, the computer can directly cause the special typewriter to type out the detailed results stored in the tape.

For this memorandum, Steps a and b above are discussed in the next section, "Trial Combat Action."

This completes the consideration of the general features and restrictions of the proposed methodology. Appendix A gives a more detailed discussion of the capabilities of the computer. The remainder of the study will develop the methodology within the limits imposed by the facts and assumptions now identified.

TRIAL COMBAT ACTION

The battle factors selected to simulate combat have been listed in general terms. To establish the adequacy of this list and aid in the formulation of the manner of their simulation a sample military situation is desirable. In this section the details of the "computer battle" are related to such a situation. It must be emphasized that the resulting system for calculation is not restricted to any specific combat situation. The rules for computation have in all possible cases been so stated that a change in the battle situation requires only that certain characteristic (coded) numbers be changed. The resulting codification of battle will be reexamined from the point of view of generality and flexibility in the last section.

SCOPE OF TRIAL CALCULATIONS

It is desirable to use the simplest possible trial combat action in establishing the feasibility of the proposed methodology. Contrariwise, the combat action to be analyzed must be large enough to be self-contained; i.e., it should include as many as possible of the significant factors that influence the battle once the forces are joined. Thus, if the action is to include a grouping of tanks, the battlefield must be large enough to include all, or most, of the elements that interact with those tanks. That armored vehicles are of special interest to this study is suggested by these considerations:

(a) Tanks represent the largest capital outlay and give rise to one of the major logistical problems of the Army, particularly under the conditions of atomic warfare.

(b) Current doctrine implies strongly that the decisive combat actions will involve strong tank forces.

(c) Tanks are combat elements severely restricted by their mechanical characteristics and thus are more clearly susceptible to mathematical analysis than less mechanical systems.

If tanks are to be included, then the smallest self-contained battlefield will be of a size comparable to the maximum effective range of their guns, i.e., about 1 to 2 miles on a side.

An intense combat action on such a battlefield could involve about a company of tanks; a smaller unit would lack tactical flexibility. Since the smallest meaningful action is desired it follows that the trial combat action should be of company size.

Even at this small scale, operation of tanks without infantry is unlikely; therefore, along with appropriate infantry units the major anti-infantry weapon (indirect fire) must also be included.

A complete combat action on such a battlefield could conceivably be completed in as little as 30 min, if the action were of sufficient intensity. In this case the action would not involve logistical problems during the action, and they could be properly left out of these trial calculations by taking certain levels of supply as basic assumptions.

Similarly, TAC is outside the necessary scope of a feasibility study. The much larger range of TAC aircraft requires that their influence be assessed in a war game on a scale where alternative allocations of strikes during an assault are feasible.*

These considerations are suggestive of the type of combat action that may serve as a test vehicle. The trial combat action should (a) emphasize tanks; (b) feature intense action—lasting about $\frac{1}{2}$ hr; (c) include company-sized units with reasonable attachments of infantry and indirect-fire weapons; and (d) take place on battlefield of one or a few square miles.

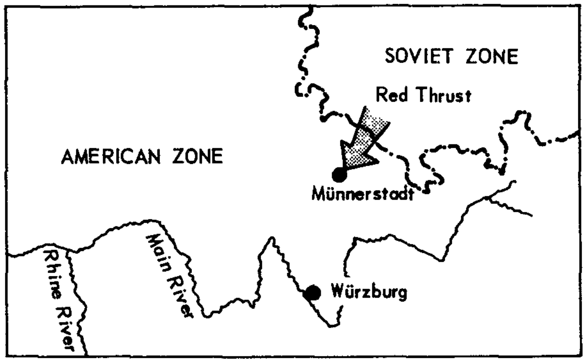


Fig. 3—General Military Situation Leading to Trial Combat Action

THE MILITARY SITUATION

A military adviser to ORO during the early part of the study formulated a military situation that might generate a combat action having the characteristics just described. It is a hypothetical situation constructed for these special purposes and is not presented as being either a typical situation in some future war or as representing a typical mission for the troops involved.

A heavily reinforced Blue infantry battalion is given the mission of delaying a Red mechanized division, in column, for a period of 12 hr at Münnerstadt, which lies about 30 miles south of the zonal (East German) boundary at Meiningen on a railroad line to Würzburg (Fig. 3). Delay is to be effected by forcing the Red

*Since both logistical and TAC air support may be important parts of the smallest unit actions, proper provision for these factors must be made when the methodology is applied. It will be shown that the methodology is flexible enough to permit inclusion of these factors, when necessary, by using more capable modern computers.

forces to deploy under heavy fire at the river line, which is the northern boundary of Münnerstadt.

Attached to the reinforced infantry battalion is a reinforced medium tank company of M48's, and a heavy mortar company. Figure 4 shows the troop disposition.

Before the Blue battalion had fully occupied its position in and about Münnerstadt, the point of the main Red column approached and was brought to a halt under fire. The Red point began to deploy, sending a strong force to cross the river on the right flank of the Blue position. Red combat engineers succeeded in quickly erecting a temporary bridge, and a company of 10 T-34's, a company of 5 SU-100's and a company of infantry crossed the river and assembled on a hill nearby. They could then bring direct fire on sections of the road south of Münnerstadt along which the Blue forces must soon withdraw. Further, they would quickly attempt to cut that road in an enveloping maneuver.

In the face of this threat, the Blue forces committed their reserve tank company reinforced by three squads of infantry mounted in three armored personnel carriers (a "scratch" force, since TO&E does not include carriers). The mission of this force was to push the Red force back across the river in preparation for the withdrawal of the Blue forces in Münnerstadt. The resulting armored assault is the action programmed for the computer.

THE BATTLE

The tactics of the counterattacking Blue force are to provide (a) an assaulting group composed of two platoons of M48's (10 tanks) and the platoon of infantry (3 armored vehicles, one squad each); and (b) a covering force (overwatching) composed of the CO, FO, and one tank platoon (total 7 tanks). In addition, the company of heavy mortars (4.2-in.) is available in direct support. The remainder of the Blue force is heavily engaged elsewhere with the Red point and cannot be assumed to assist in this operation.

The assault group moves toward the Red bridgehead, keeping in a draw as far as possible and then making a frontal assault (Fig. 4). The overwatching tanks provide support fire from cover and concealment at a range of about 1500 yd.

The Blue infantry dismount from their carriers when the Red position is closely approached. The Blue mortar fire is lifted at the same time. The mission of the Blue forces is to move on through the Red position, firing as they go. Since the battle will feature intense action with one or the other force decimated in a half hour or less to meet the requirements generated in the section, "Time Limitations," no further mission for the Blue forces is required.

The analysis of the tank attack consists of three major steps: (a) identify the interdependence of the selected battle factors for each of the combat elements on the battlefield; (b) develop a system whereby the computer can compute the basic activities of each of the combat elements on the battlefield, using experimental data giving the capabilities of the individual combat elements; and (c) provide the means for the computer to arrange the possible basic actions of the individual combat elements into a sequence of fire and maneuver activities reflecting the sense of a stated tactical doctrine.

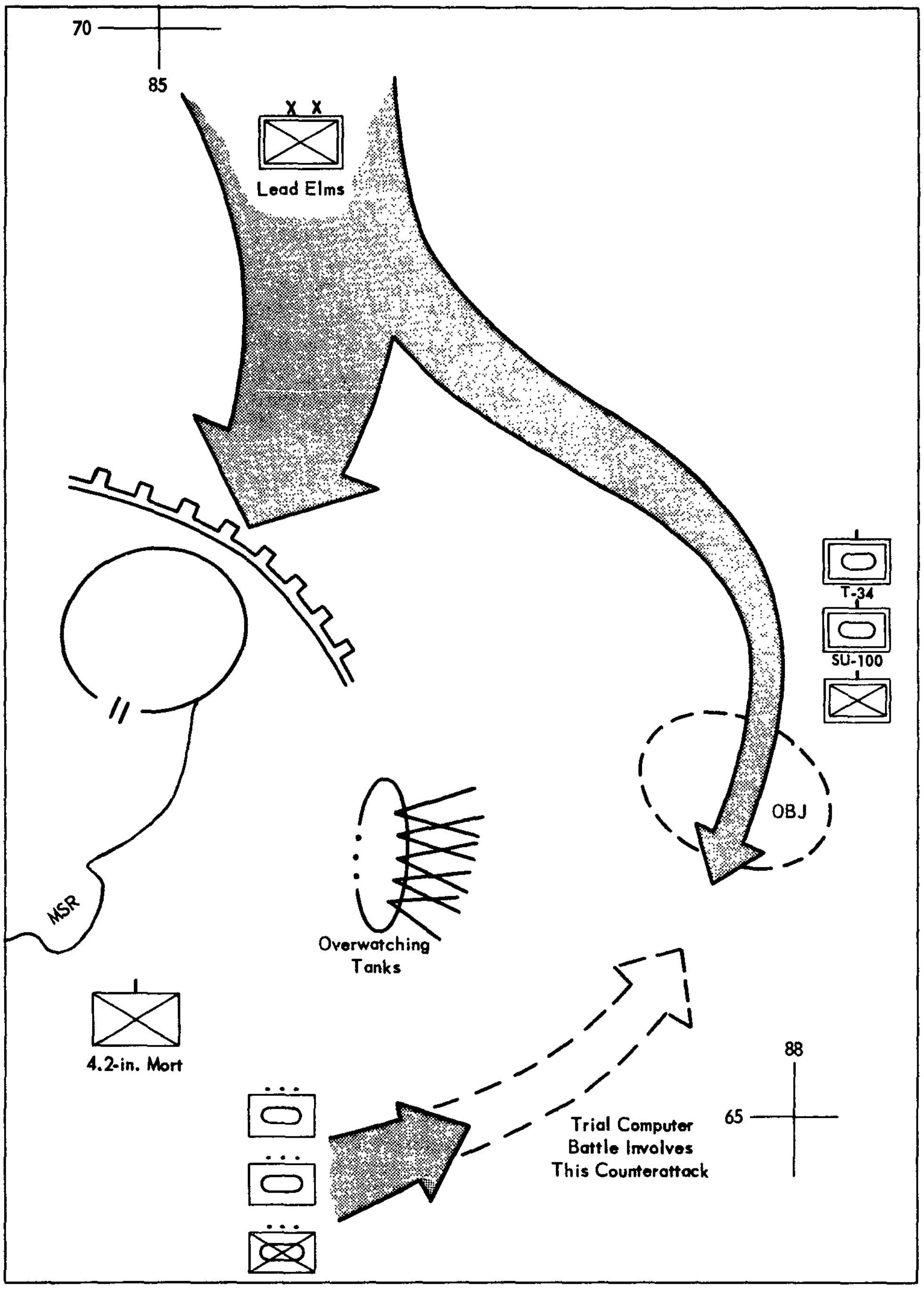


Fig. 4—Initial Disposition of Forces in Trial Combat Action
Reproduction of Overlay to AMS M841 Sheet 5727, Münnerstadt 1:25,000 (Fig. 6)

This study carries out these three steps for the trial battle described only to the extent required for demonstrating the feasibility of the methodology within the physical limitations of the ERA 1101 computer.

TERRAIN FACTORS

Since all the battle factors depend basically on the terrain factor, they cannot be discussed in detail until a means for inserting terrain factors into the machine is selected.

The major alternative means of including factors of terrain considered are discussed in App B, and the reasoning behind the method selected for this feasibility study is presented.

Essentially, the choice made is to dissect the battlefield into the largest number of small grid squares consistent with the capacity of the computer to be used. With the battlefield under consideration this results in each square being 100 m on a side for a total of 576 squares over the entire battlefield of about 2 square miles.

The average terrain factors for each square are listed and stored in the memory of the computer. These factors include the average elevation of the grid square and the average concealment afforded by the vegetation on the square, in five steps from completely open fields to dense forest. The presence of selected special characteristics such as swamp, military crest, steep slope, and a road or trail is noted.

The data giving the terrain features that are stored in the machine's memory are used by the computer in accounting for the battle factors associated with each separate action of fire or maneuver.

For example, one of the 10 battle factors is the probability that one combat element will "see" another. One essential component of this factor (but not the only one) is the identification of those enemy units in plain view of the tank attempting to pick up a target. If the elevation of all squares is known, then the computer can determine whether any square between shooter and any enemy unit is so high as to cut off the view of the shooter. If there is one such square, then that particular enemy unit could not possibly be a potential target. Similarly, if the enemy unit is in the midst of dense forest, then it cannot be seen by the shooter, even though no intervening ground interrupts the line of sight.

Dissecting the battlefield into squares also serves to make specific the fundamental actions of movement that (it is proposed) when assembled comprise maneuver. Thus the maneuver of the fundamental combat units may be considered as being made up of a series of elemental decisions, each one of which can be reduced to the following form: A combat element is on square A on the battlefield. It has the capability of moving to any one of the eight adjacent squares (Fig. 5) in some brief interval of time. (It may also remain in its present position, making a total of nine possible courses of action.) <u>Formulate the rules that will permit the combat element to make a realistic choice among these nine possible courses of action</u>.

Thus it is seen that, if the terrain of the battlefield map is put into the machine's memory in the form of the average terrain features of distinct (small) squares, it is possible to provide approximate but specific answers to the type

of terrain problems one expects in the course of computing each separate elementary combat action of fire or movement.

Coding the Terrain for the Computer

Figure 6 is a one-color copy of the battlefield section on a standard military contour map. The map has superimposed 100-m grid lines that divide the map into 576 separate terrain squares. Figure 7 shows more clearly the contours. Using this figure, the elevation of each square was determined by interpolation to the nearest meter.

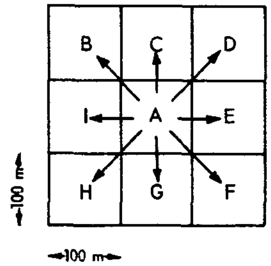


Fig. 5—Elemental Move Decision

A tank on square A has the option of moving to any of the eight neighboring squares or remaining on its present position

Figure 8 shows the average terrain features of each 100-m grid square, both natural and artificial, except for vegetation. Figure 9 shows the average concealment offered by each 100-m grid square as inferred from the vegetation indicated on the original contour map. The significance of the various degrees of concealment is in their influence on the probability that a combat unit within that square will be picked up as a target; or, once picked up, on the kill probability of another weapon against that combat unit due to the influence of partial concealment on hit probability; and also on the speed with which a combat unit can (or will) move across that square. The quantitative effect of all these terrain features on the assumed performance characteristics of the combat units is described in App C for each of the combat elements involved. The "slow" squares were determined by inspection of the contour map. Detailed performance data for the armored vehicles together with doctrinal discussion would be required to support any final evaluation of which grid squares may be properly termed "slow."

Special Terrain Calculations

Numerous references must be made to the line of sight between two squares during the course of the battle. During the firing calculations, one of the criteria for selecting a target must be that there is no intervening terrain feature that would cut off vision between the square containing the shooter and the square containing the potential target. In the present formulation of the battle, the treatment of this factor is by far the most critical portion of the calculations. No

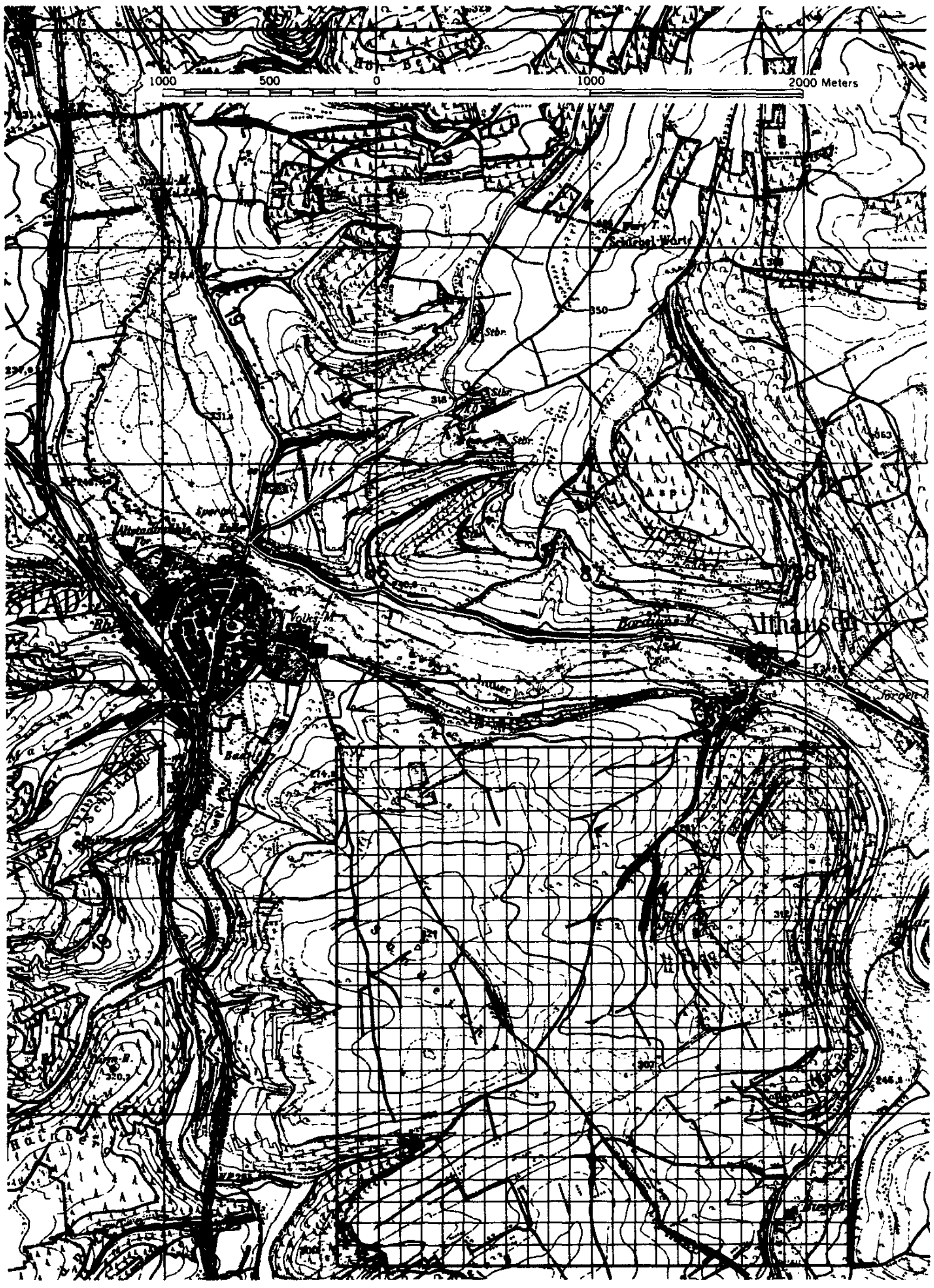


Fig. 6—One-Color Copy of Battlefield Section from Military Contour Map AMS M841 Sheet 5727, Münnerstadt 1:25,000, with 100-m Grid Lines Superimposed

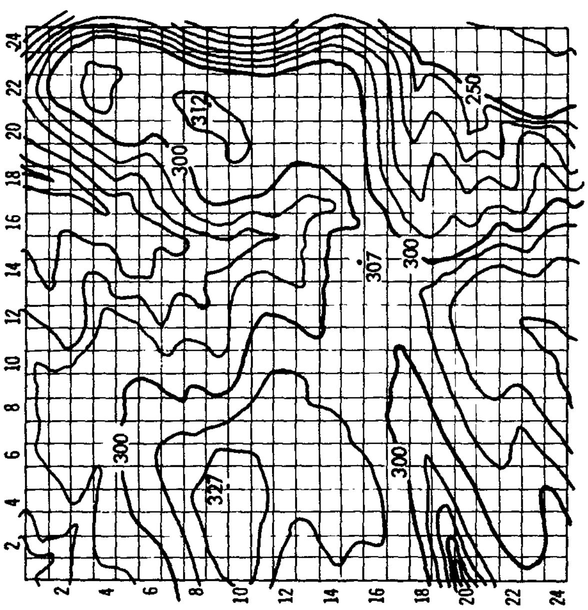


Fig. 7—Topography of Battlefield Section (10-m Contour Intervals) with 100-m Grid Lines Superimposed

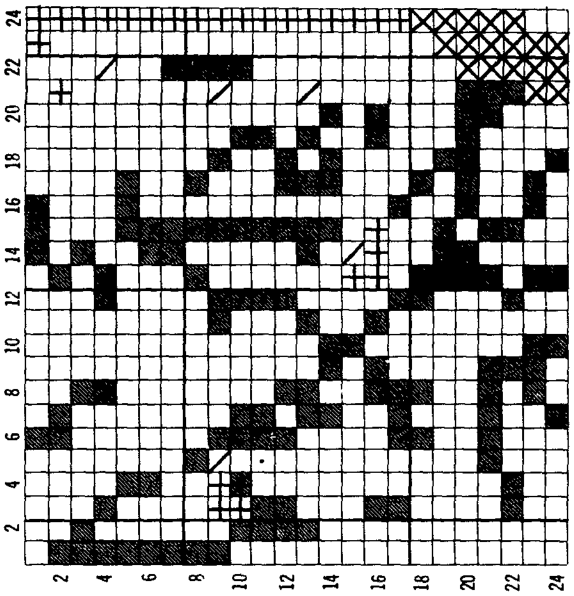


Fig. 8—Terrain Features of 100-m Grid Squares except for Vegetation

- Grid square contains trail
- Grid square is (mainly) swamp
- "Slow" square—steep hill or approach to crest
- Crest of hill (or saddle)
- No significant features

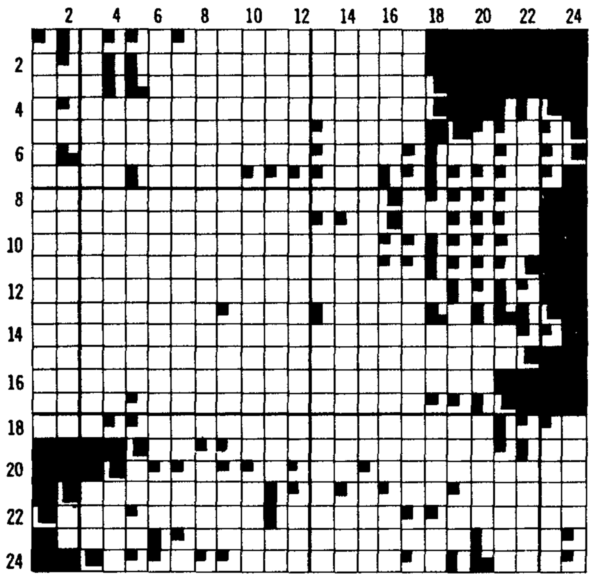


Fig. 9—Average Concealment Afforded by Natural Vegetation on 100-m Grid Squares

Open | Quarter concealment | Half concealment
Three-quarters concealment | Full concealment
Firing position on edge of full concealment

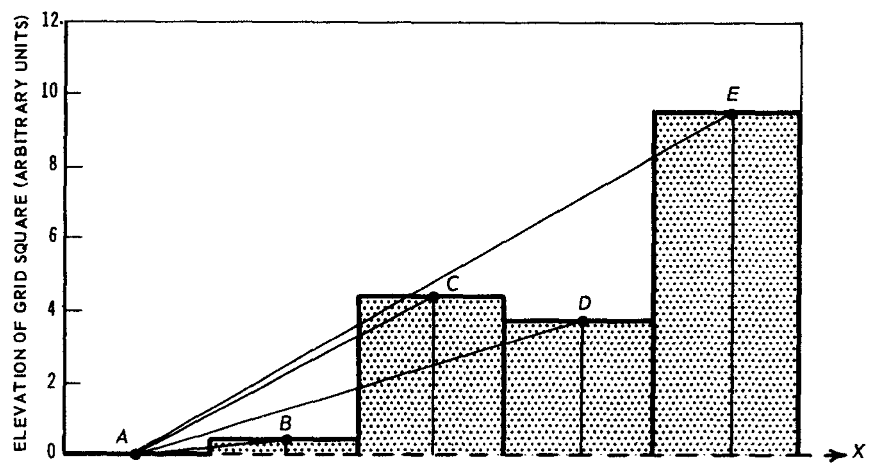


Fig. 10—Profile of Five Adjacent Grid Squares Showing Determination of Line of Sight between Shooter and Potential Target

Shooter at *A* can see target at *B*, *C*, and *E* but cannot see target at *D* because angle *CAX* is greater than angle *DAX*. Note in this approximation the "edges" of each "square" are ignored

other factor so strains the capacity of the computer. Nowhere else is the importance of the advantages that accrue from the use of logical calculations so clearly demonstrated.

The calculation required to show whether or not there is a terrain feature cutting off vision is straightforward but tedious. It involves computing for each intervening square the angle between the horizontal and a line drawn from the surface of the shooter's square to the surface* of the intervening square. As is shown in Fig. 10, if this angle is everywhere smaller than the vertical angle formed by the shooter and the target with the horizontal, then there does exist a line of sight and it is at least physically possible for the shooter to pick up this potential target.

This calculation could have been carried out during the battle only as the need arose. In the present series of calculations, using the ERA 1101 computer, it proved much more economical (timewise) to determine the existence of a line of sight between all possible squares before the series of battles begins. Once done the calculation need not be repeated for additional battles so long as the same terrain section is used and the limits on the positions of the Red forces are not changed. However, storage and use of such large quantities of data do pose problems. Appendix B discusses these problems in detail.

It is conceivable that for other types of battle and/or using different computers the advantage of carrying out this calculation in advance of the battle will disappear.

SIMULATION OF MANEUVER

The battle factors that should influence the movement of a tank or infantry squad from grid square to grid square on the battlefield have been briefly mentioned. The division of the battlefield into small squares, 100 m on a side, has been made. It remains to describe the specific manner in which the terrain factors, enemy actions, and tactical decisions shall influence the movement of the combat elements.

A partial list of the factors that must influence movement are (a) desirability of remaining in present position and firing; (b) direction to terrain objective; (c) whether or not currently under enemy fire; (d) character of terrain differences among possible new position, e.g., swamp, thick concealment, crest of hill, steep slope; and (e) presence of enemy fire on neighboring positions.

To do this, each of the eight neighboring squares plus the square presently occupied is scored separately on its desirable characteristics. For example, one neighboring square might be allowed 25 points if movement to that square is directly toward the terrain objective. Another square might be given a score of only 5 points if movement to that square is directed to one side of the terrain objective, and a square on the opposite side of the present position away from the terrain objective could be scored as 0, or even negatively, so far as contributing toward reaching the terrain objective is concerned.

Thus a series of scores—or ratings—is adopted, which is to be associated with each square on various counts of possessing desirable or undesirable terrain features, or exposure to enemy fire, or other factors that are proposed to contribute to the desirability of movement to that square. The total of all the

*In the event that the intervening square is covered with dense forest, the surface is taken to be the top of the tree stand. For these test battles, all tree stands are assumed to be 20 ft in height.

individual scores for each square gives a number. The higher this number the more desirable movement to that square at that particular time appears to be, insofar as the tank commander can determine. At this point it would be possible to have the computer select, as the next position for the combat unit, that square which has the highest rating. It is essential that the reasoning behind rejecting this possibility receive careful attention.

There are several different reasons for the rejection and several different ways of looking at those reasons. One way of putting it is to assert that all performance data to be inserted into the battle must be capable of being determined by field experiments or by a study of history. But it is clear that, were a number of different tank commanders put in the same position on the battlefield under identical circumstances so far as could be determined, then all the men would not choose the same square (or even a square in the same general direction) as their next position. Thus the ratings could not be completely determined by experiment, not even in principle, since in the experiments there would surely be some variation in choice among different men.

Another way of looking at the same problem is to consider the case where two squares in quite different directions have nearly the same total rating, e.g., differing by only 1 percent. If the computer always chooses the square with the highest rating, then this is tantamount to asserting that the rating numbers are so accurately known that it is reasonably certain which is the more desirable. It would seem to be overly optimistic to assert that experiment in such a complex matter (or a study of history) could ever produce answers with such certainty.

A third point of view is to consider whether it may be important to determine the influence on the outcome of a battle of various assumed degrees of variability in the response of men to the same situation. Thus it might be argued that weapon system A is better than weapon system B because A functions better with men who have received only 6 months of training than does B; although if all men could receive 6 yr of training B would be the better choice. In other words, the extent of the variation in the response of different tank crews to the same situation might be considered as related in part to the thoroughness of training. An investigation of the influence of nonuniform responses to similar situations may therefore be given a practical interpretation.

Each of the three points of view presented above points toward the inadequacy of a system where the computer always chooses that square which acquires the highest rating. The simplest alternative to such a rule is to cause the computer to interpret the rating numbers as the relative probabilities with which the combat element will choose its next position among the adjacent squares. This is what is done in the proposed model of battle.

Probabilities in this model of battle are always treated by the Monte Carlo technique. Thus the computer actually chooses only one of the nine possible squares as its next position, <u>but the probability that any particular one is chosen is caused to be the same as the probabilities computed for that grid square on the basis of the appropriate battle factors</u>.

On the other hand there will undoubtedly be some situations where it is desirable to remove even a slight chance of moving into some particular square. This is accomplished in the present calculations by allowing negative ratings to be assigned for certain special situations. If these negative values are made sufficiently large they will cancel out any possible positive score the square

might acquire from other considerations. The computer then is instructed to consider only positive ratings as a valid relative probability, and hence there is no chance of selecting that (negative value) square.

There is also the possibility of suspending the entire rating process in emergency cases and making selection of a particular square a certainty. This has been done in the present calculations for the special case where a tank has just moved from a concealed position and has been fired on. If the target discovers that it is under fire then the target always returns to the concealed position.

Thus the methodology is flexible enough to permit considerable modification of the maneuver calculations should that prove desirable for special cases.

Appendix C gives an example of a move decision based on the rating system described here as well as the numerical values used in rating all grid squares during the trial calculations.

SIMULATION OF FIRING

Consider first the problem of simulating the fire of the main gun on a tank. Given the correct "kill" probability for the circumstances applying to any particular round, a Monte Carlo (coin-flipping) decision can easily be made by the computer to determine whether the given round did "kill" its target. Thus suppose that the correct kill probability for the round is known to be 0.4. Then if the computer chooses a number at random between 0 and 1, there is a 40 percent chance that the number so chosen will be less than 0.4 and a 60 percent chance that it will be greater than 0.4. Thus the computer will be using the proper probabilities if it makes its decision as to whether the target was killed by the given round by calling a "kill" if the randomly selected number is less than 0.4, a miss if greater than 0.4.

Appendix A describes a standard procedure by which the computer can "choose a number at random."

The above discussion clearly leaves out most important factors in the "firing" action. In particular, it is also necessary to (a) select a target and (b) decide to fire at the target.

The decision to fire or not to fire at the selected target depends on (a) whether the tank is physically capable of firing, i.e., has a loaded gun that has been laid on the target, and (b) a tactical decision on the desirability of firing at that particular time.

The selection of a target means that the potential targets already picked up by the tank commander are made the subject of a priority system that eliminates all but one of the potential targets.

This suggests a systematic statement of the time sequence of events in an elemental action of firing; at least for a tank firing its main armament. It is summarized by the flow diagram shown in Fig. 11.

It will be recognized that the diagram does not allow for all eventualities. For example, there is the real possibility that something may occur to change the tank commander's mind during Step 4 while the turret is being rotated, or that Step 1 should follow Step 2, so that the decision to fire depends in part on

what types of target are available. Tentatively, however, the flow diagram in Fig. 11 will be taken as approximately describing the essential character of the elemental combat action of firing the main gun on a tank.

Step 1 requires a (tactical) decision as to whether the particular tank was on a fire mission. This is accomplished in this study by a decision made in advance of the actual computations.

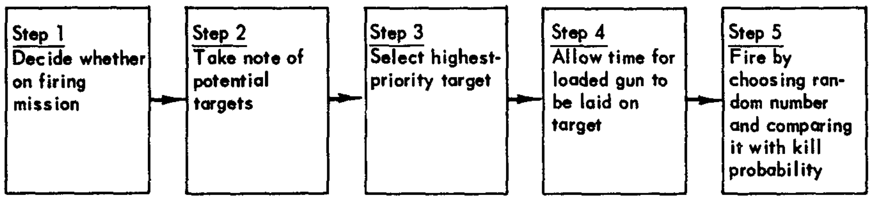


Fig. 11—Steps in Firing Calculations

A systematic description of various steps leading up to firing a single round

All tanks will fire, given a target, as soon as physically possible to do so except* that (a) no firing by assaulting combat units is permitted until one of their number reaches the edge of the Red position, and all other combat units open fire at this same time; or (b) firing begins 15 (battlefield) min after start of battle, whichever is the earlier.

Step 2 involves those computations listing all potential enemy targets known at the time to the tank commander who is searching for a target. Thus it is necessary to determine which enemy units it is possible for the tank commander to see by reason of cover (elevation) and concealment (vegetation). Other factors involved are:

(a) Identification of those enemy units which disclosed their position by fire or maneuver to any member of the opposing side, together with the probabilities that all units of either side will share such knowledge through the radio net.

(b) Recollection of those enemy units which have previously been actually noted by the tank commander.

(c) Identification of those enemy units which are placing fire on the tank in question.

Step 3 involves selecting among the potential targets that one which has the highest priority. The priority system used in the present battle is, from the highest to the lowest class of targets:

(a) The tank firing at the shooter (random choice if more than one).
(b) Tank that was last target.
(c) Any tank (make random choice if more than one).
(d) The infantry unit firing at the shooter (random choice if more than one).
(e) The infantry unit last fired at.
(f) Any infantry unit (make random choice if more than one).

*This limitation was principally a practical one, so as to stay within the time limits on use of the computing machine for the feasibility calculations. When firing was permitted to start with the onset of the assault, the computer calculations consumed an hour per battle, three times too long.

Step 4 involves establishing that the gun has been reloaded and is laid on the target. Time has already passed sufficient for the gun to have been reloaded and for minor adjustments of the gun's sighting before the tank was selected by the computer for processing. However, if the target selected in Step 3 is a new target, then an additional time delay is required while the turret is traversed and the gun accurately laid on target. In the trial calculations a constant delay of 8 sec is allowed for this when necessary.* When the tank is selected again for firing, it has thereby been allowed the necessary time for laying its gun on target and will be able to fire immediately, unless in the meantime the target has disappeared from sight or has been killed, or another target of higher priority has become known to the shooter.

Step 5 involves the actual firing. The principal calculation at this point is to determine the correct kill probability for the particular set of circumstances. The kill probabilities are stored in the computer's memory and depend on the following seven factors:

(a) Type of shooter (weapon).
(b) Shooter moving or not.
(c) Type of target (armor thickness—size).
(d) Target moving or not.
(e) Range to target.
(f) Cover and concealment available to target (e.g., hull defilade or in edge of forest).
(g) First or subsequent round by shooter.

The last section of Step 5 carries out three calculations:

(a) Records casualties, if any.
(b) Determines the time interval required to reload and relay the gun.
(c) Determines whether shooter has disclosed his position to enemy.

This completes the general description of the basic firing action by tanks. In the case where an infantry unit is firing, the computations are exactly the same, although the interpretation is somewhat altered.

Small-arms fire is considered as being lumped into discrete units of fire (or bursts) delivered at the same rate as the main armament for the tanks and at comparable rates for the infantry units. Since the infantry units in the present model of battle are taken to be squads and involve more than one discrete fighting unit (more than a single man), on the average, one burst of small-arms fire would not totally destroy the entire infantry unit. Thus infantry targets are treated differently than tank targets. Most generally the fighting potential of such a unit would be reduced by a fraction. For example, under the proper circumstances, one 30-sec burst of machine-gun fire from a tank might reduce the effectiveness of an infantry squad by one-fourth. Determination of the proper fraction involves not only the number of casualties but also the influence of such a loss on the effectiveness of the remainder of the squad.

With the above difference noted, the general treatment of firing suggested by the five steps in Fig. 11 will be considered to apply to all combinations of tanks and infantry, with suitable adjustment of the performance characteristics.

*Existing higher-capacity computers will permit the time delay to depend on the angle through which the turret is to be moved.

The mortar fire is treated as a special case in the present model of battle. Only an "average" treatment is given of the five steps just outlined for firing the tank gun. The steps are:

(a) Grid square (to be impact area of a salvo of 12 mortar rounds) is selected at random from the general area occupied by the Red forces.

(b) If there are infantry units within the selected 100-m grid square, then a degradation factor (which is a function of the cover and concealment afforded by this area) is applied to the infantry strength of the unit.

(c) The time interval before the next salvo will be fired is computed.

BATTLEFIELD TIME

Step 4 in the systematic treatment proposed for the elementary combat action of firing (Fig. 11) requires that the computer "allow time for loaded gun to be laid on target." Computations of the movement of tanks and other combat units require that the proper time be allowed for the combat unit also to reach its new position before the computer considers still another change of position. Thus both elementary combat actions require reference to the passage of time in the simulated battle.

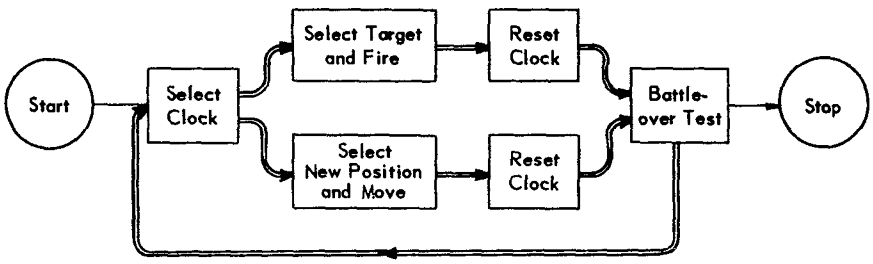


Fig. 12—Flow Diagram Showing Way in Which Computer Maintains Order in the Sequence of Moving and Firing Calculations

The computer keeps the calculations of the various elements on the battlefield in a proper time sequence by the use of what will be called "alarm clock words" or "clocks" for short. Ignoring for the moment certain complications arising from compromises made in this first coding of the battle, the treatment of time, using the "alarm clocks" is indicated by Fig. 12.

In the operations box, called "select clock," the computer checks the times when each tank or other combat unit is able to perform its next activity, either movement to an adjacent square or a search for a target, firing when possible. The tank or unit that is able to act at the earliest time is chosen by the computer for the next calculation. The clock box determines what this action will be, either a move or an attempt to fire.

The firing or moving box then carries out the necessary calculations to select a target and shoot, or to decide where the tank will move next. The results of these actions, including any effect they will have on the future activities of other tanks, are also recorded.

The reset boxes end the firing or moving calculations by determining when the particular unit will have completed the action just started and hence may be chosen again by the clock routine for additional treatment.

For example, when a moving calculation results in a move to a neighboring square, there must be a certain delay before the tank reaches this new position. The delay will depend on the distance to the next position and on the speed with which the tank moves, which in turn depends on the character of the ground between these positions and also on whether the tank stops to fire along the way. The reset calculation takes these factors into account and determines what the necessary delay must be. Then the move clock of this tank will be set up the necessary amount in time preventing subsequent moves from occurring prematurely.

After leaving the reset operation boxes the course of the two types of combat action calculations rejoin, entering the battle-over-test operation box. At this point it is determined whether the battle computations should be terminated. Tests are made to establish whether the appropriate criteria have been met. In the present battle the calculations are stopped if either (a) all the tanks on either side have become casualties or (b) the battle time has reached 30 min.

If the battle has not ended in the battle-over-test box, then the computer returns to the clock operation box and selects the next combat unit to be carried through the calculations. Thus the closed loop indicated in Fig. 12 by the thickened arrows is traversed repeatedly throughout the battle, along one or the other of the two major branches, firing and moving. In the present battle this computation loop is repeated, on the average, about 1600 times for each battle and consumes about 0.75 sec of the computer's time per loop.

SUMMARY FLOW DIAGRAM

Figure 13 summarizes the principal steps carried out in the course of simulating the combat action, which have been discussed. The flow diagram is largely self-explanatory.

The reset operation indicated explicitly in Fig. 12 has been absorbed into the over-all firing and moving operation boxes. The reset calculation is still performed but at various stages of the calculation, depending on the circumstances. For example, there are four different outcomes (or "exits") of the firing calculations indicated in the flow diagram. One of these, outcome 3, is used only when the battle is over, hence no reset calculation is necessary. Each of the other three outcomes—1, 2, and 4—requires a separate and distinct reset calculation since the battle continues. For outcome 1 the reset calculation must allow an appropriate time delay for the tank crew to "survey the terrain" and receive a few radio reports giving the position of enemy units before being given another opportunity to fire. In the present battle a time delay varying between 30 and 62 sec is imposed for this purpose.

Outcome 2 in the firing routine imposes an 8-sec delay whenever the target selected requires that the turret be rotated and the gun relaid.

Outcome 4 imposes a variable delay that allows time for the gun to be reloaded and minor aiming adjustments made for a second shot. The delay depends on the type of tank doing the shooting and also on a probability distribution to take

account of minor variations in the crews and other circumstances (see Table C5, App C). Data from Project STALK (tests conducted jointly by BRL and OCAFF) were not available at the time these calculations were made but may prove useful for future application of the methodology.

A special operations box, barrage, is used to control the firing of the mortar battery. The clocks box includes a test on whether the mortar battery has been selected to fire (outcome 3). Although this fire could have been controlled by the firing box, the details of the calculation are quite different. Thus time would be wasted were the computer to combine into one series of calculations

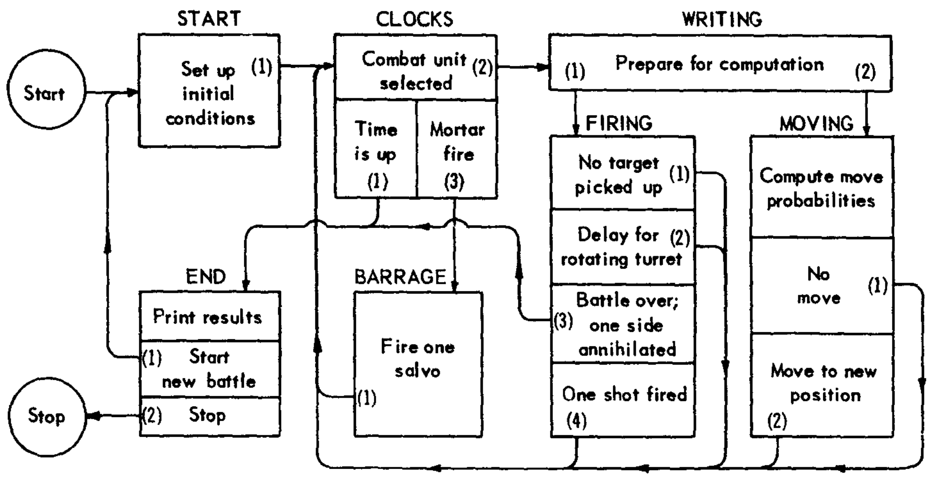


Fig. 13—General Flow Diagram for Battle

Indicated are the major components of the calculations controlling the progress of the combat action. Several of the blocks have more than one "exit" as shown by the numbers in parentheses. The choice of the proper "exit" varies as the battle progresses and is determined by detailed calculations not shown.

both types of firing. A reset calculation is included in this operation and imposes a time delay before the next salvo is fired, varying between 0 and 64 sec according to a probability distribution. The average delay is 32 sec. The target area is selected at random from the general area known to include the Redforces.

The battle-over-test box indicated in Fig. 12 has disappeared. Part of its function has been absorbed into the firing routine at outcome 3 where the test is made determining whether either side has been annihilated. A check on whether the battle has exceeded the time limit is made in the clocks operation box. For most of the test battles included in this report, the time limit was 30 min, battlefield time. Some of the battles using heavy tanks were allowed to continue for an additional $4\frac{1}{3}$ min to compensate partly for the delay resulting from their lower cross-country speed.

The detailed flow diagram of the computer battle is given in App C along with a running commentary on the various operations. The diagram has the same general format as that shown in Fig. 13.

PERFORMANCE CHARACTERISTICS OF WEAPONS

The performance data assumed for all combat units in the trial calculations are tabulated in App C.

The values used were the best readily obtainable but all values used include a modifying factor to account for combat and terrain factors not ordinarily a part of proving-ground data or theoretical calculations. This modifying factor was in all cases an estimate obtained from a limited number of experienced officers and civilian analysts.

In summarizing, a military situation that generates a small combat action meeting the requirements developed in the introduction has been described. The combat action itself has been "dissected" into simple combat actions occurring on small sections of terrain. A series of precise calculations and decisions have been proposed, which, taken together, afford a systematic means for calculating the outcome of each separate elementary combat action of fire and maneuver. Finally a system for recording the passage of battlefield time that will permit the computer to maintain a sensible sequence in the order with which the separate elementary combat actions are computed has been described. The rules and numerical values used are described in great detail in App C.

CONCLUSION

The preceding description (including Apps A, B, and C) of how the trial combat action is designed constitutes the evidence supporting the second conclusion of the study: The technique permits direct participation of nonmathematical personnel—most importantly, officers with extensive combat experience—at every significant step of the design and criticism of controlled, scientific war gaming.

RESULTS OF TEST BATTLES

Results of the trial calculations are required for two purposes:

(a) To establish the spread* of battle outcomes deriving from the nature of the model of battle, and from the spread of results to assess the statistical reliability of average battle results.

(b) To establish the sensitivity of the average battle outcome to a significant alteration in the performance characteristics of the Blue tanks only.

Once these two parameters are determined it is possible to specify the number of repetitions of the battle that are required to indicate, for instance, the better of the two tank designs.

The principal results of the trial calculations are applied in this section to this determination. A detailed tabulation of all available battle results is given in App D.

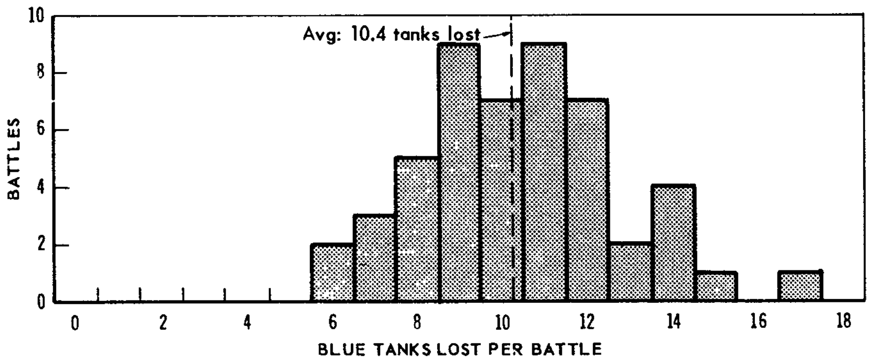


Fig. 14—Distribution of Blue Medium Tank Losses in 50 Battles with Red Tanks
σ = 2.33 tanks per battle

SPREAD OF BATTLE RESULTS

The most basic characteristic of the model of battle described in this memorandum is the influence of the play of chance that is included. Figure 14 shows the variation in the number of tank casualties suffered by the Blue side,

*"Spread" as used here is equivalent to the standard deviation of the distribution. For normal distributions this is the interval about the mean which includes 63 percent of the cases: Table 1 gives the spread of all the casualty distributions presented.

equipped with medium tanks, in 50 battle calculations that differed only by virtue of the play of chance. Figure 15 shows the variation in Red tank losses (T-34's and SU-100's) during the same 50 battles. Although on the average Red suffered 7.1 tank casualties per battle compared to Blue's average losses of 10.4, it is

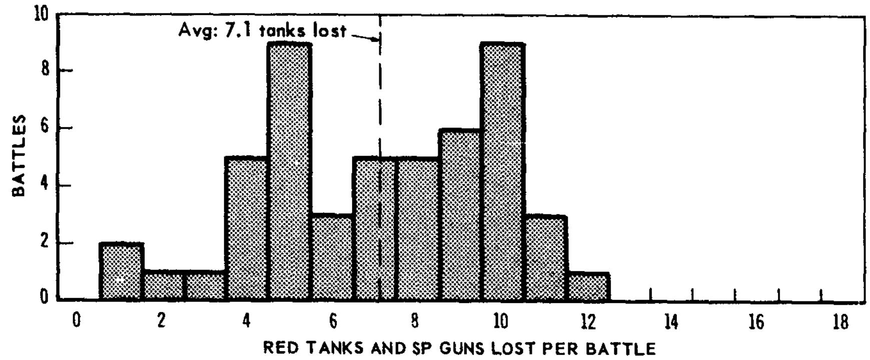


Fig. 15—Distribution of Red Vehicle Losses in 50 Battles with Blue Medium Tanks

σ = 2.74 tanks per battle

evident there were many departures from this average. Figure 16 shows that in 6 of the 50 battles the Red losses were actually larger than the Blue losses. This fact is indicated in Fig. 16 by the 6 points above the dashed line, along which the losses on both sides are identical.

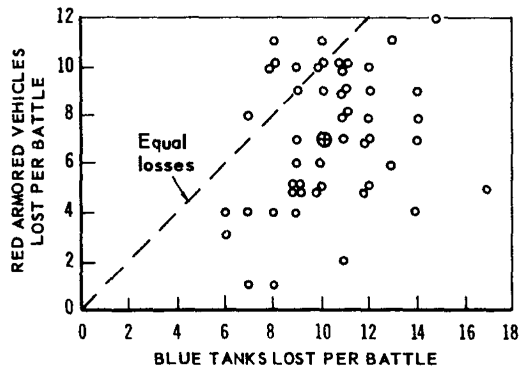


Fig. 16—Scatter Diagram for Comparing Red and Blue Tank Losses in 50 Medium Tank Battles

⊕ indicates point for average losses, viz., 7.1 tanks and SP guns, and 10.4 Blue tanks

If the number of battles were increased beyond 50, the spread in tank losses indicated by Figs. 14 and 15 would in all likelihood not be changed significantly. There is only 1 chance in 1000 that it should vary by more than plus or minus 30 percent. Hence the degree of spread in the results is mainly characteristic of the battle model and the performance characteristics of the man-weapon teams alone.

The important corollary to the spread in results effected by any given weapon design is the concomitant number of times the battle computations must be repeated to reveal differences among competing tank designs.

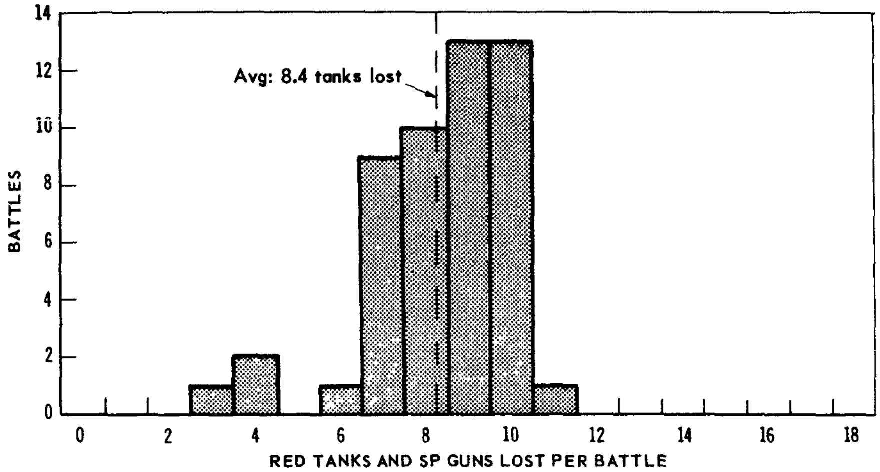


Fig. 17—Distribution of Red Vehicle Losses in 50 Blue Light Tank Battles
σ = 1.66 tanks per battle

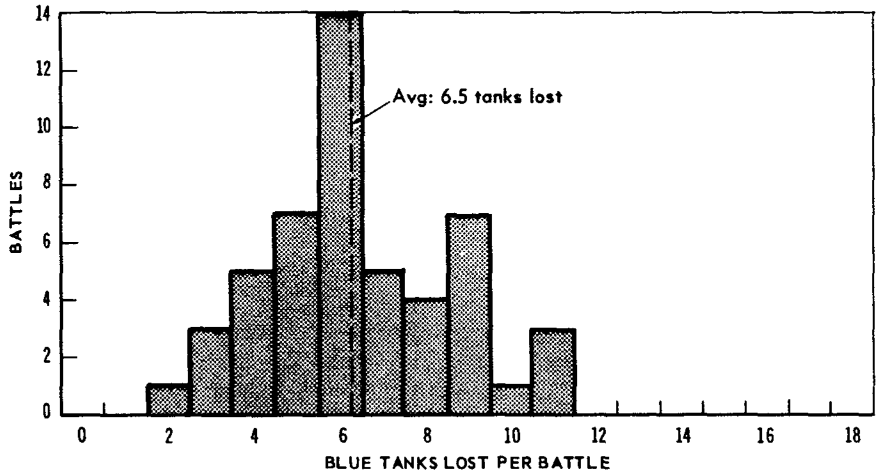


Fig. 18—Distribution of Blue Tank Losses in 50 Blue Light Tank Battles
σ = 2.38 tanks per battle

To investigate this feature of the methodology, 50 additional battles were computed for the case where the Blue medium tanks were replaced by the same number of hypothetical light tanks. All other features of the battle situation remained as before. Figures 17 and 18 show the distribution of the number of

tank casualties experienced by both sides in this second series of battles. On the average, Red lost 8.4 tanks in each battle, whereas Blue lost an average of 6.5 light tanks per battle. Thus, based on the average number of tank casualties alone, the Blue hypothetical light tank was more effective than the Blue medium tank. In particular the average effectiveness ratio* for the Blue medium tank battles was 0.6 (to the disadvantage of Blue) whereas for the hypothetical Blue light tank the effectiveness ratio was 1.14 (to the advantage of Blue).

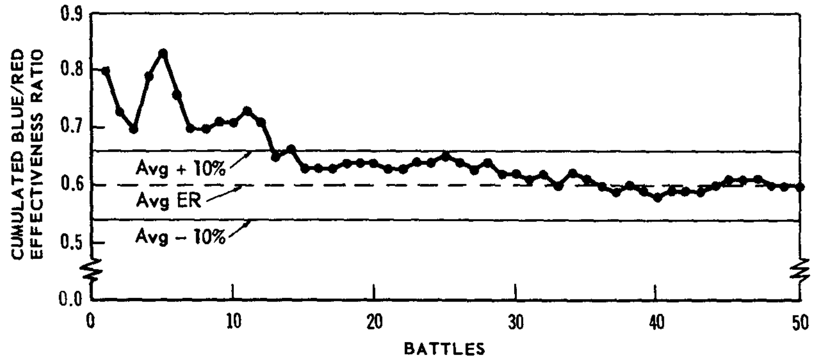


Fig. 19—Variation in Computed Effectiveness Ratio (ER) of Blue Tanks over Red Tanks as the Number of Battles Used for Computation Is Increased

$$ER = \frac{\text{average number Red tanks killed by each Blue tank}}{\text{average number Blue tanks killed by each Red tank}}$$

It is at this point that the degree of spread in the number of tank casualties in the various battles must be considered. The two effectiveness ratios 0.61 and 1.14 calculated above are statistical approximations to the "correct" values that would have been produced had the battle computations been repeated an "infinite"† number of times. Thus there is always the chance, however remote, that both these numbers are so much in error that, in fact, the Blue light tank is actually less effective than the Blue medium tank. It is possible to reduce the risk that such an erroneous conclusion would be drawn to any size however small, at the expense of increasing the number of test battles.

Application of standard statistical tests on the reliability of these test results shows that the odds are overwhelming against (better than 360,000:1) the possibility that either one of the two series of 50 battles incorrectly identified the winning side. Appendix D describes these statistical calculations.

The conclusion is that a sample size of 50 battles was sufficient to demonstrate the superior killing powers of the Red tanks in this series of battles. Indeed, a substantially reduced number of repetitions would probably have been acceptable. Figure 19 shows what the computed effectiveness ratio for the Blue medium tanks would have been had the battle calculations been stopped after

*A simple definition of tank effectiveness has been used by V. McRae and A. Coox in ORO-T-278, "Tank-vs-Tank Combat in Korea." There, tank effectiveness was defined as the ratio of the average number of enemy tanks killed by each friendly tank to the average number of friendly tanks killed by each enemy tank. Other definitions of effectiveness have been proposed, including cost effectiveness, which includes the elements of production and logistical costs.

†For practical purposes, "infinite" can be taken to mean a very large number, e.g., 1,000,000.

each of the 50 battles in turn. It will be noted that the computed effectiveness ratio varies by only about ±3 percent as the number of battle computations is increased beyond 30. It is evident that sequential sampling techniques may be applied to minimize the quantity of calculations.

The previous discussion does not require that the distributions of tank losses shown in Figs. 14, 15, 17, and 18 be normal. However, in view of the unusual character of the distribution of Red casualties shown in Fig. 15, a test on the statistical hypothesis that each of the four distributions was normal gives the results shown in Table 1. The results show that all four distributions are

Table 1

STATISTICAL TEST ON THE SIGNIFICANCE OF OBSERVED DEVIATIONS FROM NORMAL ERROR CURVE FOR FOUR DISTRIBUTIONS OF TANK CASUALTIES

Category	Mean losses	Standard deviation	Probability of observed departure from normal curve by chance alone
Blue medium	10.42[a]	2.33	0.90
tank battles	7.08[b]	2.74	0.15
Blue light	6.46[c]	2.38	0.21
tank battles	8.36[d]	1.66	0.29

[a]Blue (Fig. 14). [c]Blue (Fig. 18).
[b]Red (Fig. 15). [d]Red (Fig. 17).

well within the 0.05 level of significance.* If there were serious concern regarding whether these distributions may be approximated by normal error curves, then an appeal to statistical rigor could only be supported by the results of additional computer calculations.

Fourteen additional battles were computed for the case where the Blue forces were equipped with a hypothetical heavy tank. The Blue forces were the winners in terms of casualties in this series of battles, losing an average of 5.4 tanks per battle compared to the average Red losses of 8.8 tanks per battle. The sample size of 14 is so small as to cast doubt on the reliability of the results however. The detailed results are given in App D.

The conclusion is that a series of 50 battle calculations for each tank design may be expected to be sufficient to identify the superior tank design features in the present instance when significant variations in major tank design features are assumed.

DISCUSSION OF RESULTS

It must be emphasized that the superiority is stated only in terms of some battle result that it has been agreed will indicate superiority. Clearly there are different aspects of superior performance. For example, in the preceding calculations, relative tank killing power has been used as indicating superiority.

*So long as the probabilities are greater than 0.05 that the observed deviation from a normal curve could be due to chance alone, the assumption that the distributions are normal is tenable.

Other factors could have been used in its place. Thus, superior Blue performance could have been measured solely in terms of the destruction of the Red forces regardless of the Blue losses sustained in the attack. Or superior Blue tank performance could have been taken as being indicated solely in terms of the number of Blue tanks that were able to reach the terrain objective. Or any combination of these features could have been used to measure superior performance. The purpose of this feasibility study is not to formulate the criteria of superior performance but to provide the means for simulating battle so as to permit identification of superior performance once it has been defined.

Appendix D gives in considerable detail the history of the battle calculations.

CONCLUSION

The trial battle calculations just presented (and in App D) constitute the evidence supporting the first conclusion of this memorandum, viz., the Monte Carlo technique enables a very large number of battle factors to be introduced into a feasible analysis of the performance of alternative weapons and weapons systems. The number of battle factors warrants designation of the computing system as a battle simulator.

APPLICATION OF METHODOLOGY TO TO&E AND TACTICAL STUDIES

In the preceding section a detailed set of rules (culminating in the flow diagram, App C) was constructed for the express purpose of enabling a computer to war-game a particular counterattack of a reinforced Blue tank company. Limitations on the applicability of these war-gaming rules to other situations must be identified. In the light of the four essential components of combat listed in the section "Facts and Assumptions," the flexibility of the war-gaming rules will be examined with respect to each component in turn.

FLEXIBILITY OF WAR GAME

The first of these components refers to the opposing combat forces. The manner in which the Blue reinforced tank company was injected into the war game involved breaking the combat unit down into subordinate units (in this case individual tanks and infantry squads) and storing in the computer the values of each parameter to be associated with the several battle variables listed in the section "Battle Factors." Owing to the extensive use of logical computer operations, the number of distinct subunits that could be conveniently processed was limited to 24, which is the number of "bits"* in a computer number. Thus, so far as the war-gaming rules are concerned, the subunits in the war game can correspond to any military fighting units whatsoever, so long as their killing power, rates of fire, vulnerability, "seeing" probability, communicating ability, and mobility may be specified. For example, the 20 combat units that constituted the order of battle of the Blue forces could be caused to correspond instead to 20 separate infantrymen, with appropriate values for the performance characteristics.

On the computer it is entirely feasible to scale all the physical measurements up so that the calculations may be interpreted as involving the killing power, vulnerability, and mobility of platoons of tanks instead of individual tanks, and platoons of infantry in place of squads of infantry. With 24 such units the overall combat action then involves a heavily reinforced battalion maneuvering on a battlefield of perhaps 6 to 10 miles on a side with grid squares of perhaps 300 m on a side.

However, for such calculations to be significant, it is necessary that fairly accurate performance data for the fundamental combat units be available. One possible source of such data is the careful study of the smaller company-sized actions proposed for CARMON.

*"Bits" are to the special computer numbers as "digits" are to ordinary numbers (see App A for details).

Thus there is no technical limitation to any desired expansion of the scale of the calculations, retaining approximately the same time limitations. The problem is solely in terms of the availability of performance data for the subunits.

If time restrictions are relaxed, then a number of complete company-sized actions may be joined to form a battalion-sized action, while retaining the present detailed dependence on individual tanks and squads of infantry.

However, as the scale of combat is increased (i.e., involves either longer combat actions, or higher combat echelons), the lack of nonfighting units in this type of battle code becomes serious. This is particularly true of resupply operations. The present battle code does not allow for resupply. However, it is evident that inclusion of such noncombat resupply units does not raise any new problems. Thus the same attention to the mobility of resupply subunits is required as is already provided for combat subunits. The "terrain objectives" of such resupply subunits would, of course, be the combat units themselves or a supply dump. For present purposes, however, the scale of combat it appears feasible to treat does not involve any large resupply effort.

Earlier it was mentioned that TAC was ignored in the feasibility study. It should be evident at this point that selected subunits in the computer order of battle could have such numerical values assigned for their battle factors as to cause them to correspond to TAC aircraft or TAC units. However, as was also mentioned earlier, the simulation of a combat action is useful only insofar as it permits investigation of the variation of combat results for significant alternatives. For such small-unit actions as are under consideration here, alternative TAC strikes cannot be made. The only choice would be a decision to lay on a TAC strike or to refrain from doing so. In the latter course the impact of the alternative TAC missions on the war is not being assessed by the simulator itself. It follows that weapons whose scale of potential application far exceeds the scope of the battlefield being simulated should be inserted into the battle simulation only indirectly as boundary conditions or in terms of influence on doctrine.

All 20 subordinate units of the Blue forces could be interpreted as individual infantry battalions if the numerical values used for the six classes of performance characteristics were appropriately selected. Doubtless this is currently difficult, if not impossible, owing to the lack of comprehensive data. But the war-gaming rules themselves do not prohibit such use, were the data available.

It would therefore appear that, so far as the first essential component of combat is concerned, the war-gaming rules developed for the tank counterattack are not generally restricted to any particular type of unit.

Although it is clearly possible to design much more complex models of battle than that used here, including both additional battle factors and much more detailed relations between them, such a venture would ordinarily involve construction of a second code for the computer and is beyond the scope of this study. The mission of this study is to test only the feasibility of constructing a single code for the computer which may be applied to many situations, within wide limits, with no modification of the code, but only modification of the numerical value of selected parameters.

Consider the second "essential component of combat"—the battlefield. The use of a grid-square system of storing terrain information is clearly not restricted to the particular battlefield chosen for these sample combat calculations. Neither must their size be restricted to 100 m on a side. The limitation on the

use of grid squares is in the number of squares that can be processed quickly and the quantity of detailed terrain information stored for each square. The size of a grid square can be varied to suit the circumstances, consistent with the accuracy required in specifying the position of any particular combat unit.

The third "essential component of combat"—the mission—clearly may be varied in any specified manner. Any number of terrain objectives may be identified, or other missions stated.

The fourth component—tactical doctrine—enters into the war-gaming rules in a more subtle fashion.

MODIFICATIONS OF TACTICAL DOCTRINE

The war-gaming rules require three major types of decisions of each simulated battle participant repeatedly throughout the calculations. These are:

(a) Choice of which (adjacent) grid square is to be next occupied.
(b) Selection of a target from among available enemy combat units.
(c) Decision to move or fire, or to refrain from doing so.

The rationale motivating this series of decisions constitutes the tactical doctrine being applied. However, the numerical values inserted into the computer to govern and control this series of decisions include the influence of whatever human factors are assumed to limit or otherwise modify the "pure" expression of doctrine.

For example, the doctrine governing the first class of decisions above for the Blue assaulting tanks was very elementary, being simply to attack, rather directly, the enemy position after debouching from the draw. However, the numerical values of the parameters used to cause such a series of move decisions (the "terrain weighting" numbers) permitted considerable transient variation in each individual decision. This variation (i.e., the use of probabilities) is to be interpreted as representing the combined effect of the individual's military training (i.e., his knowledge and application of doctrine), modified by his own personal inclinations (i.e., his departure from the use of doctrine). The particular set of numbers to be used for the simulation of any particular series of combat actions represent the assumed level of training, morale, and the selection of a scheme of maneuver. The choice is entirely at the discretion of the operator of the battle simulator.

If desired, the numbers used may correspond to "robotlike" tank commanders whose responses show no variation from tank to tank and show no departure whatever from a rigid interpretation of a proposed doctrine.

At the other extreme the numerical values may be selected to correspond to a "disorganized mob," with extreme variation among individual tank behavior and extreme departures from the tactical doctrine under study.

The same considerations may apply to the second and third classes of decisions. However, as was discussed in App B, for the special purposes of this feasibility study certain practical limitations were placed on the convenience with which such alterations could be made.

Thus the fourth and last component of battle simulation—tactical doctrine—may be varied at will in the same manner, and within the same limits as the first three components, i.e., the order of battle, the terrain, and missions of the opposing forces.

APPLICATION TO ERA 1103 COMPUTER

The scale on which the Monte Carlo methodology may be applied to analysis of TO&E studies must be assessed in terms of a particular design of computer. The one selected for present purposes is the ERA 1103 now installed at ORO. Of course, any high-capacity computer* could be applied but the details would likely be quite different.

This computer is similar to the 1101 computer used for the trial calculations insofar as a part of its memory is the same 16,384-word magnetic drum. However, in addition there is a very fast memory of 1024 words (magnetic core) and a slow auxiliary tape memory of 262,000 words. The order structure is similar for the two machines. The 1103 computer words are 36 bits† long.

Owing to the extensive use of logical operations, the number of distinct combat elements on each side should not exceed the number of bits in each number used by the computer. For the 1101 computer this was 24; hence the maximum number of combat units was 24. In the 1103, these numbers are 36 bits long, and hence each side may have up to 36 distinct combat units and still retain the speed associated with logical operations.

The 36-bit words therefore allow inclusion of heavily reinforced company-sized combined-arms teams to be used on both sides. For example, Blue may consist of a tank company (17 tanks) with a platoon of heavy tanks attached (5 tanks) and two platoons of armored infantry (6 squads plus 2 platoon HQ plus 2 LMG sections plus 2 mortar sections) for a total of 34 distinct combat elements.

For similar reasons, the main battlefield may consist of up to $36 \times 36 = 1296$ grid squares, provided storage of necessary data is not prohibitive. If 100-m grid squares continue to appear to be a useful approximation, this could result in a battlefield of up to 3600 m on a side.

Although the auxiliary magnetic tape memory of the 1103 has a large capacity, access to this storage is time consuming. Thus its contents can only be consulted infrequently throughout the battle. Therefore at any given time during the battle calculations the action under consideration by the computer should be entirely within some 36- by 36-grid-square area. On the other hand there is adequate storage to permit the battle to progress gradually from one 36- by 36-grid-square area to another, if the time restrictions are relaxed somewhat.

CARMON: A REFINED BATTLE CODE

The battle code applying the techniques developed in this feasibility study has been designated by the name CARMON.

Refined Moving Calculations

With the increased speed of the ERA 1103 computer, it is practicable to make a number of refinements in the calculation of move probabilities. Thus the move probabilities of any given combat unit can be made to depend on the

*For example, the IBM 704, the Remington Rand UNIVAC, the Bureau of Standards SEAC, the Aberdeen ORDVAC.

†This is equivalent roughly to a 12-digit number. The term "bits" is required since the computer uses binary numbers. Appendix A discusses this feature of electronic computers.

fields of fire of known or suspected enemy positions. The raw data for effecting this were already present in the calculations for the feasibility study. However, time limitations prevented the use of the precalculated line-of-sight data for this purpose.

It is also practicable to improve the calculation of the delay that firing activities impose on moving. Thus, whereas moving in the feasibility study was adjusted for the average case of 2 rounds fired for every 100-m advance, the delay in moving can now be tied directly to the time lost while firing.

In addition the cross products of two terrain features may be included. Thus the presence of two distinct terrain features on the same square, e.g., edge of heavy forest plus swampy area, may be accorded a rating independent of the rating allowed for these two terrain features separately.

Also, the increased capability of the 1103 computer permits the influence of the terrain features of each grid square to be related to each adjacent square in turn. Thus, if one grid square contains a road, the influence of that road on movement from an adjacent square depends on whether the pair of squares in question is linked by the road. In other words the existence of a road or river is less a significant characteristic of a single square, and more a characteristic of a pair of squares. The number of such pairs of squares is four times greater than the number of squares alone, and hence the need for a higher-capacity computer than the 1101 to include this effect.

Finally, provision can be made to impose a formation on a group of combat units. This can be done by means of the dependence of the move probabilities on a terrain objective. Thus if the platoon leader (tanks or infantry) takes account of the terrain objective in his calculations, while each member of the platoon moves with reference to the changing position of the platoon leader, then the members of the platoon can be caused to maintain a specified posture relative to the platoon leader, while the entire group advances toward the terrain objective.

Firing Calculations

With the increased capacity of the ERA 1103 computer numerous refinements may also be made in the firing calculations.

One such refinement is the angular orientation of a target at the time it is struck by a round. By allowing each tank always to have established an orientation relative to the battlefield that depends on its own direction of motion, or its recent firing activities, the angular aspect of a target relative to the shooter can also be determined. Once determined it can be allowed to influence the kill probabilities and perhaps also the tactics.

A second refinement is possible relative to the priority lists used in selecting a target. It is practicable to classify units in terms of the range and allow this factor to influence the selection of a target.

Infantry Calculations

The added capacity of the ERA 1103 computer will permit the infantry squads to be accorded three different sets of kill probabilities corresponding to (a) the rifle components, (b) the automatic weapon component, and (c) the

antitank component. The significance of distinguishing between these factors is that the different components have distinct vulnerabilities and performance characteristics.

The military posture of the infantry squads may also be related in more detail to the battle circumstances. For example, the squads may be (a) advancing rapidly, firing, and upright; or (b) advancing slowly, firing, and crawling; or (c) stationary and firing from hoxholes; or (d) stationary but not firing owing to the volume of fire they are receiving.

Communication System

Information about the enemy or friendly forces acquired during the battle calculations is shared with other friendly elements depending on the facility of the entire communication system. The techniques applied in the feasibility study permit such sharing of information to be limited by parameters that reflect the operational performance characteristics of the communication system.

Specifically, each act of sharing information may be delayed by a time t, after which the bulk of the information is available to some other combat element with probability R; there is a probability D that the critical part of this information will be incorrectly interpreted. The three parameters t, D, and R thus characterize the capabilities of the communication system.

Imposing a time delay on the sharing of information requires that the clock technique be used. Hence a third clock, the communication clock, is to be added to the two already present: the moving clock and the firing clock.

The application of the probabilities D and R follows the same general pattern as that already established in these feasibility calculations (App C).

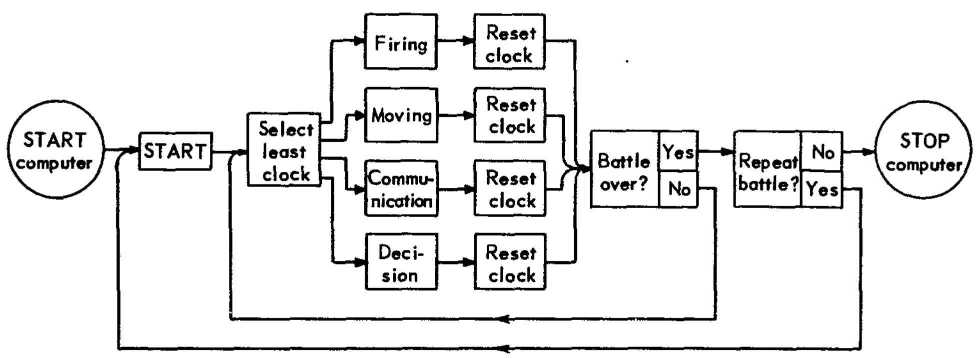


Fig. 20—Simplified Flow Diagram for CARMON

INTRODUCING COMMAND DECISIONS

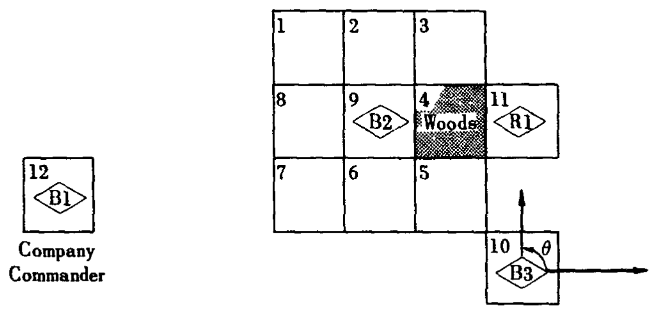
The feasibility calculations implement a simple tactic at the lowest level by means of the tables of values to be used in the calculation of move probabilities, the priority list used in selecting a target, and the choice between moving and firing. For example, the rating numbers used in this feasibility study correspond to a frontal assault by the Blue assault group. Other tactics (defend,

envelop, or infiltrate) would require a different set of values to be used in the rating calculations that produce the move probabilities. Thus the feasibility study already contains the system required to implement a variety of tactical alternatives. It is therefore feasible to allow appropriate variations in the tactics of different combat groups as the battle progresses. All that is required is that, on the basis of information compiled by a unit commander at any echelon (using the communication system already discussed), the commander select among the tables of values associated with these several tactics that one which he desires his subordinates to follow. So that his decisions are properly ordered in time, a decision clock that functions in the same way as the other three clock types must be provided.

Figure 20 shows the flow diagram for the principal calculations (similar to Fig. 12). As a concrete example of the workings of this generalized system, Table 2 shows a sample application of the system. This hypothetical calculation illustrates the manner in which the interactions due to the communication system are taken account of, while retaining the basic features of the 1101 battle.

Table 2

HYPOTHETICAL CARMON CALCULATION



Battlefield time, sec	Calculations	Results of reset calculations			
		Communication clocks	Decision clocks	Firing clocks	Moving clocks
195	B3 (square 10) picks up R1 (square 11), decides to send emergency message to B2 (square 9), computes that message will be transmitted with 10-sec delay to B2 and B1 (square 12), that B3 will have turret rotated through angle θ and fire first shot at R1 in 25 sec (at 220); (sets clocks as indicated in right columns)	B1 205 B2 205		B3 220	(Set previously) B2 200
200	B2 decides to move to square 4 and will reach edge in 35 sec (at 235)				B2 235
205	B2 receives message from B3 and computes that it heard it correctly; computes also that in 4 sec will stop; B1 receives message from B3 but incorrectly hears unit as T-34 instead of	B3 214			B2 209

Table 2 (continued)

Battlefield time, sec	Calculations	Results of reset calculations			
		Communication clocks	Decision clocks	Firing clocks	Moving clocks
	T-54; checks criteria and decides to ask B3 for repeat; query is computed to get through with 9-sec delay				
209	B2 stops moving and decides to return to original position, reaching there in 9 sec (at 218)				B2 218
214	B3 hears B1 request for repeat of message; computes this will be done in 15 sec	B1 229			
218	B2 arrives back at square 9; rerates squares, searching for position covered from R1, chooses square 2, commences move, computing will arrive at border in 45 sec (at 263)				B2 263
220	B3 gets off first shot at R1; misses; computes that R1 will become aware of this with 10-sec delay at 230 and that B3 itself can get off second shot in 8 sec at 228	R1 230		B3 228	
228	B3 misses second shot at R1; computes third shot in 8 sec (at 236)			B3 236	
229	B1 receives correct message from B3; checks battle decision criteria, noting that this is 10th T-54 tank in area in front of B2 and B3 noted and still alive; decides that assault group which includes B2 and B3 will take up covered firing positions immediately while second assault group maneuvers around to the flank of T-54's to get on objective; computes that B2 and B3 group will react to this order in 50 sec (at 279)		B2 279 B3 279		
230	R1 learns of fire by B3, backs up to previous covered position calculating that it will leave line of sight to B3 in 25 sec (at 255)				R1 255
236	B3 checks on firing third shot at R1, discovers R1 is now moving target and delays firing for 7 additional sec (at 243)			B3 243	

SPECIAL "TELEVISION" DISPLAY SYSTEMS

The utility of a battle simulator fashioned with the techniques described in this memorandum is twofold. First, the outcome of a series of battles may indicate the superiority of a proposed weapon or system design. Second, once identified, the superior performance indicated by the battle outcome may be

justified and explained; i.e., the reason that superior performance results from the performance characteristics may be identified clearly so that the results (a) may be examined for plausibility, and (b) then be exhaustively checked by detailed analysis and field or proving-ground experiments.

To facilitate the second application it is necessary that the progress of a series of battle computations be easily inspected as well as the outcome of the battle. The presently available equipment records the progress of the battle calculations in very lengthy tabulations. It is expensive in time and money to reconstruct in a meaningful way the battle situations from such tabulated data.

This inspection process may be enormously simplified if certain television-type cathode-ray-tube systems are connected to the computer in such a way that the progress of the battle is continuously displayed on the face of the tube in terms of conventional military map symbols. Such equipment is well developed and can be adapted to most large general-purpose computers, including the ERA 1103 computer.

TRAINING

Particularly with the addition of appropriate display devices, the system could have application as a training device. In this case an external operator would replace the "automatic commander" in the battle. The external operator would have available only the summary information that would otherwise be available to the "automatic commander" and would make the same type of decisions; i.e., fix terrain objectives, specify the scheme of maneuver, and make such alterations in these orders as is appropriate as the battle progresses. The system could be used with a human operator on only one side or with both sides so controlled. The battle calculations could be made at a rate consistent with real battle or at an accelerated rate. The electronic modifications of the computer required to facilitate such control over the progress of the battle are easily carried out.

CONCLUSION

The preceding description of how the scope and detail of the model of battle may be changed constitutes the evidence in support of the third conclusion of the study in the section immediately following.

CONCLUSIONS

The conclusions drawn from this study relate only to the limited objective of the memorandum, i.e., to test the feasibility of the Monte Carlo small-unit war game.

The design and results of the trial combat action justify the first conclusion below. The actual, detailed process of designing the trial combat action justifies the second. The entire discussion of alternative procedures and general areas of application justifies the third.

1. The Monte Carlo technique enables a very large number of battle factors to be introduced into a feasible analysis of the performance of alternative weapons and weapons systems. The number of battle factors is sufficient to warrant designation of the computing system as a "battle simulator."
2. The technique permits direct participation of nonmathematical personnel—most importantly, officers with extensive combat experience—at every significant step of the design and criticism of controlled, scientific war gaming.
3. The battle factors used are sufficiently comprehensive and basic to permit great flexibility in the manner of their combination into various combat situations involving a variety of weapons and at any echelon for which the performance characteristics of the weapons systems may be specified.

Owing to the limited objective of this study, there are no formal recommendations.

Appendix A

CAPABILITIES OF THE ELECTRONIC COMPUTER

CONTENTS

THE COMPUTER

Selected performance data of the computer is given in Table A1.

Table A1

PERFORMANCE DATA FOR ERA 1101 COMPUTER

Item	Amount
Memory capacity, 7-digit numbers	16,384
Max[a] additions (or subtractions) per sec	15,000
Max multiplications per sec	3,000
Total number of possible distinct operations	43
Time to fill memory from tape, min	8½
Digits (or alphabetic characters) typed per sec	10

[a]These maximum performance levels cannot always be achieved for reasons discussed in the next section, "The Magnetic Drum."

Computer Calculation

The significant types of calculations, or operations, which the 1101 computer can perform may be listed under three general categories:

(a) Arithmetic Operations: Ordinary addition, subtraction, multiplication, and division.

(b) Logical Operations: A special form of arithmetic designed for carrying out a type of calculation akin to "logical reasoning."

(c) "Jump" Operations: A special class of operations that makes it possible for the computer to alter the scheme of calculation depending on the result of some previous numerical or logical calculation.

Every automatic calculating machine has at least a few operations of each type listed above. In addition there are other less significant operations, which stop and start calculation of the computer, and which cause the computer to punch or type out selected results, to "read" numbers punched into the input tape, and perform other necessary but subordinate functions.

Since the ERA 1101 computer has a definite list of possible operations, every step in the computer battle is ultimately stated in terms of one or a few of these operations. Annex A1 lists these orders in some detail.

The computer battle described in this memorandum makes important use of all three classes of operations. In general any calculation expressed in terms

of a logical operation could also be reduced to an arithmetic one. However, tremendous savings in time and memory capacity, as well as an increased simplicity of conception, is possible when logical operations are used.

For the present a simple example of each of these three basic types of operations is given. Elsewhere the combat action is described, dissected into its components, and finally translated into a series of instructions for the computer in terms of these basic operations.

A Simple Arithmetic Operation. The computer could be caused to carry out this operation: "add the number of Blue tanks killed (number is stored at place X in memory) to the number of Red tanks killed (number is stored at place Y in memory) and store the sum at place Z in memory." It takes three separate steps for the computer to perform this simple addition:

Step 1. Take number stored in place X (memory) and put into "adder" (in arithmetic unit).

Step 2. Take number stored in Y and add it into the adder.

Step 3. Take sum now in adder and put into place Z.

A special number code is used to cause the computer to perform each step.

A Simple Logical Operation. The computer could also be caused to carry out this operation: "there is a number composed of 5 digits that may be either 1's or 0's, e.g., 10110." The first digit* is a 1 if the first tank has been killed, a 0 otherwise. The second digit is a 1 if the second tank has been killed, it is a 0 otherwise; and similarly for the interpretation of each position in the number; with the third digit relating to the third tank, the fourth digit to the fourth tank, and the fifth digit to the fifth tank. This 5-digit number is stored at the place X in the computer's memory. Question: is the third tank a casualty?

Step 1. Take number in X and put in adder.

Step 2. Take number in Y (number is 00100) and put into adder; form the "sum" of the number in X with the number in Y using the convention that the number expressing the sum will contain a 1 in a given position if both the number in X and the number in Y have a 1 in that same position. Otherwise the digit in that position in the sum is to be a 0. Carrying this out shows:

Number in X	10110
Number in Y	00100
Sum	00100

Step 3. Is the sum in adder different from 0? If it is then the third tank is a casualty.

The preceding example identifies the number resulting from combining the number in X with the number in Y as a sum. Logicians call it a "logical product." This type of operation plays an extremely important role in the computer battle. It is discussed in much greater detail in the remainder of the memorandum. A special number code causes the computer to perform these three steps in about 1/5000 of a sec.

A Simple "Jump" Operation. The computer may be caused to calculate this: "stop the computations and type out the letter R if the total number of

*The digits in a number composed only of 0's and 1's are usually called "bits" when used with computers.

tanks killed (e.g., calculated in the preceding example of an arithmetic operation) is as much as 17." The steps for carrying out this calculation are listed below.

Step 1. Put the number from place U (this is the number 17) into the adder.

Step 2. Subtract the number from place Z (this is the total number of tanks killed computed in the previous example of an arithmetic operation) from the number in the adder. The adder now contains the difference between the number in U and the number in Z.

Step 3. Test the size of the number in the adder. If it is exactly 0, go to Step 4. If it is not 0, go to Step 5.

Step 4. Cause the typewriter to type out the letter signified by the number in place W. Then stop the computer. (Note: The place W must have inserted into it before the start of the computations that number which will cause the typewriter to print R.)

Step 5. Go to the next proper step for continuing the battle.

There is a precise number code that will cause the computer to carry out these steps in as little as $\frac{1}{5000}$ sec.

The Magnetic Drum

The body of this memorandum includes a general description of the ERA 1101 computer and its capabilities. Both the strength and weakness of the computer derive from the fact that its entire memory is in the form of a rotating drum. The strength results from the large capacity of the drum. The weakness results from the time delays required while the computer waits for the rotating drum to bring a desired number into a position where the control (Fig. 2 in text) can "send" it to the arithmetic unit.

Other sections of this memorandum indicate the necessity of the large memory capacity and the reason for choosing the ERA 1101 computer for these calculations.

Since the drum rotates with an angular speed of 3500 rpm, each revolution of the drum consumes 16 msec. Thus any given position on the drum will, on the average, require a delay of half a drum revolution or 8 msec before it swings under the heads which "read" the number and "send" it to the arithmetic unit. Since the arithmetic operations themselves are carried out very rapidly, the delay imposed on the computer while waiting for the drum to rotate is the principal contribution to the calculation time. In order to reduce such delays as far as possible, very sophisticated schemes of coding are used under the general category of "minimum access programming." It would be outside the scope of this memorandum to discuss this further. However, the operations of the control and arithmetic units are discussed. Since application of this methodology is expected to make use of the ERA 1103 computer which largely eliminates the minimum access problem, the omission is appropriate.

LOGICAL OPERATIONS

An important feature of the ERA 1101 computer (and to some extent most modern high-capacity computers) is the system of logical operations it can perform. An essential factor in this capability is the fact that most modern

computers use the so-called "binary number system," with which all numbers are indicated by a series of 1's and 0's; e.g., 1100101011 = 811. Annex A2 describes the way in which this system of numbers (and arithmetic with the numbers) operates.

For present purposes the significant feature of the binary system is the ease with which it can be altered so as to carry out logical operations with enormous speed. This capability will be demonstrated by an example that has direct application to the methodology described in this feasibility study.

TARGET IDENTIFICATION

Let there be associated with a given combat element on the Blue side (e.g., a tank) a binary number consisting of 24 positions (or bits). The convention is established that the leftmost bit of this number will be a 1 if the combat unit has previously seen the Red (enemy) combat unit 1. Otherwise this bit will be a 0. Similarly, the second bit from the left in this binary number will be a 1 if the Blue combat unit has previously seen Red combat unit 2. Similarly for each bit in turn, each one being a 1 if the Blue combat unit has previously seen the corresponding Red combat unit. For example, given a total of five enemy combat units, the binary number associated with a particular Blue combat unit might be (for convenience let this be termed the "A number"):

$$A = 10110$$

indicating that the Blue unit has previously seen enemy combat units numbers 1, 3, and 4 but not numbers 2 and 5.

If at some time during a battle calculation it is necessary to select a target for firing purposes and therefore refer to the number and position of enemy combat elements visible at that moment to the same Blue combat unit, then the information stored in the binary number just described would need to be brought up to date. Thus those enemy combat elements which had since become casualties could be removed from the list. Also those combat elements which are currently in a concealed position are not at the moment available as targets. Finally, additional combat elements may have recently betrayed their position but are not yet included in the binary number.

By making use of logical operations the binary word describing enemy combat elements previously seen may be brought up to date so as to indicate, by the same convention, those enemy combat units now seen.

The first step is to add to the binary word those combat elements which have recently done something which can be assumed to betray their position to all within sight. Suppose the list of such combat elements has been kept current in a single binary number word (for convenience, called the "B number") with the convention that the leftmost bit shall be a 1 if enemy combat unit 1 has recently betrayed its position, and a 0 otherwise. Similarly the bit second from the left shall be a 1 if enemy combat unit 2 has recently betrayed its position, and the same for all five enemy combat units. For example the B number may be

$$B = 01100$$

indicating that enemy combat units 2 and 3 have recently betrayed their position.

If the B number is added to the A number in a special way, the sum will have a 1 in all positions corresponding to enemy combat units whose position is currently known to the Blue combat unit.

$$A = 10110$$
$$B = 01100$$

$$A \oplus B = 11110$$

Inspection of the sum will show that the addition indicated by the symbol "$\oplus$" is carried out by writing a 1 in the sum provided that either or both A and B have a 1 in the same position. This special version of addition is one of the two basic logical operations.

The significant feature of the above operation is that only one operation was required to add to the list of enemy combat units previously seen those which recently betrayed their position. In the trial calculations carried out in the course of this feasibility study there are 24 enemy combat units. There are also 24 bits in the binary numbers handled by the computer. Hence the above system can be applied to bring the list of potential targets up to date for any combat unit in only one operation.

The next step in the calculations to bring up to date the list of targets available to a selected Blue combat unit is to subtract from the list those Red combat units which are now in a fully covered or concealed position.

For this purpose let there be a third binary number, to be called the "C number," which has 1's in those positions where the corresponding enemy combat unit is not now concealed and a 0 for those which are concealed. For example, suppose the C number is the following:

$$C = 10111$$

Then this indicates that enemy combat units 1, 3, 4, and 5 are not concealed, but that 2 is concealed. If the number $A \oplus B$ previously calculated is multiplied by the number C in a special way then the product will have 1's in every position corresponding to an enemy combat unit that (a) can currently be seen by the Blue combat and (b) whose position is known to the Blue combat unit. Thus,

$$A \oplus B = 11110$$
$$C = 10110$$

$$(A \oplus B) \otimes C = 10110$$

where the symbol $\otimes$ has been used to indicate the special system of multiplication where a 1 is written in any position in the product provided that both the multiplier (C) and the multiplicand ($A \oplus B$) have a 1 in that position. This special form of multiplication is the second basic logical operation, here called "logical" multiplication.

As a last step in deriving an "up-to-date" list of the enemy combat units available to a selected Blue combat unit as targets, the list must be corrected by removing from consideration those enemy combat units which have become casualties. This requires that the product derived in the last step be logically multiplied with a D number that has a 1 in those positions corresponding to

tanks not yet casualties, a 0 otherwise. To complete the example, suppose enemy combat unit 3 is the only casualty. Then

$$(A \oplus B) \otimes C = 10110$$
$$D = 11011$$

$$[(A \oplus B) \otimes C] \otimes D = 10010 = \text{current targets}$$

Thus three simple logical operations have sufficed to correct an out-of-date list of potential targets. This system is applied, using 24 Red combat elements and 20 Blue combat elements, throughout the model of battle calculations and much of the speed of the computer calculation is dependent on its use.

The preceding logical operations may also be used to inject an element of chance into such calculations. To effect this, the use of random numbers is required. The properties and use of random numbers are discussed in Annex A3.

Note that the simplicity of this system is not without cost. For it is necessary that the computer continuously correct the B, C, and D numbers as the battle progresses so they may be current.

Annex A1

ORDER STRUCTURE OF ERA 1101 COMPUTER

The computer used in this technical memorandum has a total of 42 non-trivial orders. These may be classified as shown in Table A2.

Table A2

TYPES OF ORDERS USED WITH ERA 1101 COMPUTER

Operation	No. of orders in class
Add and subtract orders with variations	15
Multiply and divide with variations	3
Transmit	5
Address substitution	1
Stop with variations	3
Shift	2
Print out	3
Jump instructions	6
Logical operations	4
Total	42

Table A3

SPECIAL LOGICAL OPERATIONS WITH ERA 1101 COMPUTER

Designation	Explanation
Q jump	If leftmost bit of Q word is 1, jump to y for next instruction, otherwise continue in normal order sequence; in either case shift bits in Q word one place to left, with leftmost bit going into rightmost position
Substitute	Replace each bit of y with corresponding bit of A, provided the corresponding bit of Q is a 1; the remaining bits of y will not be disturbed
Clear logical multiply	Clear A and then add the 48-bit number whose left-hand 24 bits are all 0 and whose right-hand 24 bits consist of the bits of y corresponding to the 1's of Q with 0's in all other positions
Hold logical multiply	Same as above except that A is not cleared initially
Complement bits	Complement those bits of A which correspond to 1's in y

These orders are nearly all of conventional type and need not be further discussed. An exception is the group of logical operations together with one of the jump instructions that play an important part in this feasibility study. Table A3 describes these five instructions. In the description of these orders, Q and A are the two registers in the arithmetic unit, y is any memory position.

Annex A2

BINARY NUMBERS AND ARITHMETIC

Owing to the degree to which the methodology proposed in this memorandum depends on logical operations as distinct from common arithmetic, it is necessary to describe the binary number system employed by many electronic computers including the ERA 1101 computer. In fact nearly all fast computers use the same number system.

In the computer all numbers may be considered as being denoted by a series of 1's and 0's alone called "bits" in contradistinction to "digits" in the decimal system. The actual number indicated may be found by adding a series of small numbers, each a different power of 2, depending on whether a given part of the number is a 1 or a 0. As an example, the binary number 1101 is interpreted to mean 13 by the following process.

$$1101$$

$$\begin{aligned} \text{means}\quad & (1 \times 2^3) + (1 \times 2^2) + (0 \times 2^1) + (1 \times 2^0) \\ \text{or}\quad & (1 \times 8) + (1 \times 4) + (0 \times 2) + (1 \times 1) \\ \text{or}\quad & 8 + 4 + 0 + 1 = 13 \end{aligned}$$

The reason for using what may appear to be a clumsy notation is that much simpler computing machines of much greater reliability may be built on this basis. Notice however the basic similarity between the interpretation of binary numbers based on powers of 2 and the familiar decimal notation which is based on powers of 10. Thus, using the system;

$$143 = (1 \times 10^2) + (4 \times 10^1) + (3 \times 10^0).$$

Addition and subtraction of binary numbers follows a series of straightforward rules similar to those for "carry" in ordinary arithmetic. Two examples of each will suffice to illustrate these rules.

Addition		Subtraction	
Example 1	Example 2	Example 1	Example 2
1 ≡ 01	7 ≡ 0111	2 ≡ 10	7 ≡ 0111
+1 ≡ 01	+6 ≡ 0110	-1 ≡ 01	-6 ≡ 0110
= 2 ≡ 10	= 13 ≡ 1101	= 1 ≡ 01	= 1 ≡ 0001

Multiplication is effected by repeated addition, and division is effected by repeated subtraction.

The ERA 1101 computer uses binary numbers with 24 bits or positions. Hence, if the decimal point is at the right, the most significant bit (the leftmost) contributes a value of $2^{23} = 8,388,608$ to the over-all number. Thus about seven significant figures may be indicated by a 24-bit binary number if such accuracy is required.

Fractions in the binary system are interpreted to involve negative exponents. For example:

$$0.0101 \text{ (binary)}$$

$$\begin{aligned} \text{means} \quad & (0 \times 2^{-1}) + (1 \times 2^{-2}) + (0 \times 2^{-3}) + (1 \times 2^{-4}) \\ \text{or} \quad & (0 \times 1/2) + (1 \times 1/4) + (0 \times 1/8) + (1 \times 1/16) \\ \text{or} \quad & 0 + 1/4 + 0 + 1/16 = 5/16 = 0.3125 \text{ (decimal)} \end{aligned}$$

Annex A3

RANDOM NUMBERS FOR MONTE CARLO CALCULATIONS

The term "random number" as used in this memorandum may be taken to mean simply that numbers are selected by some process such that each digit of the number has an equal chance that it will be a 0, 1, 2, 3, 4, 5, 6, 7, 8, or 9;* and that, if a series of random numbers is to be written down, the digits that appear are in no way dependent on the digits preceding it. The crux of the definition is that any group of numbers will be taken as satisfying this definition if accepted statistical measures of the frequency with which any given digit appears in an extended list of numbers, singly and in combination with other numbers, show the hypothesis to be a tenable one.

It is essential to recognize that, whereas drawing numbers out of a hat can be made to satisfy the definition, a scheme for the generation of numbers is possible that violates part of the definition, yet can pass the test stated in the preceding sentence.

It is not within the scope of this memorandum to discuss this apparent contradiction. It suffices to say that, for all practical purposes, numbers that are "so nearly random" to permit their use as such may be generated by the computer. They are properly called "pseudorandom" numbers.

One such scheme was used in this feasibility study. A new random number was produced when required from the previous one using a revised Lehmer[4] method:

$$R_{k+1} = R_k . C(\text{mod}\, M)$$

where R_{k+1} = new (pseudo) random number
R_k = previous (pseudo) random number
C = 29
M = 6,236,449

The pseudorandom numbers generated by this method are all less than M, and the sequence of numbers will not repeat itself before 1 million such numbers have been produced but will, of course, repeat sometime before 6,236,450 numbers have been generated.

RANDOMNESS AND LOGICAL OPERATIONS

For many logical operations associated with probabilities, it is desirable to have binary numbers having a stated probability of a 0 at every position. Each position in the binary form of every pseudorandom number generated by a process such as was described above has a 50 percent chance of being a 1 and a 50

*The fact that the computer uses binary numbers does not basically influence this definition.

percent chance of being a 0. If 0's are desired with some other probability, this can be brought about by various combinations of logical operations on these pseudorandom numbers. For example, if the logical product (Annex A1) of two pseudorandom numbers is formed, then there is a 75 percent probability that each and every position, separately, in the product will contain a 0. This follows from the fact that there is only a 1 in any given position in the product if there is a 1 in the same position in both the multiplier and the multiplicand. But there is a 0.5 chance that either of these should happen or a ($0.5 \times 0.5 = 0.25$) 25 percent chance that both would happen; hence a ($100 - 25 = 75$) 75 percent chance that this should fail to come about, yielding a 0 in the product.

By repeated logical operations, binary numbers may be produced which have, to within a stated accuracy, any desired probability of possessing at each and every position, separately, a 0. Thus, if logical multiplication is denoted by $\otimes$, logical addition by $\oplus$, and every random number by r, the following list shows some of the possibilities (exponent -1 indicates that all 0's are changed into 1's and all 1's into 0, i.e., the "complement bits" order in Annex A1).

Operation	Chance of 0, %
r	50
$r \otimes r$	75
$(r \otimes r)^{-1}$	25
$r \otimes r \otimes r$	87.5
$(r \otimes r \otimes r)^{-1}$	12.5
$r \otimes r \oplus r$	37.5
$(r \otimes r \oplus r)^{-1}$	62.5

Annex A1 shows the two logical operations. Logical addition is performed using the substitute order in Table A3.

Appendix B

ALTERNATIVE BATTLE MODELS

CONTENTS

CONTENTS (CONTENTS)

INTRODUCTION

In the body of the memorandum a series of decisions are made to use various particular techniques to restate the combat action in a form amenable to computer calculations. In most cases there are several alternative means of effecting this. This study has made a particular choice among these alternatives consistent with the limitations on the feasibility study. But from time to time it will be reasonable to review the alternatives to determine whether additional experience and modified circumstances indicate a different choice to be advantageous. To aid in such periodic reviews of the methodology, the most important alternatives will be described in this appendix along with the reasoning that prompted each choice made.

The alternatives discussed include the various ways in which the terrain features may be introduced into the computer, the use of tabulated weapon performance data contrasted with formulas, and the use of special logical operations. These alternatives are keyed to the capabilities of different types of computers and to the nature of the problem areas to be analyzed.

INTRODUCING TERRAIN FEATURES INTO THE COMPUTER

The most basic feature of the proposed methodology involves a scheme for effecting direct reference to the terrain features during the battle calculations. The major alternatives to the proposed battle model therefore naturally involve the way in which the terrain features are made a part of the calculations.

There appear to be three essentially different means of including the effects of terrain: (a) the use of mathematical formulas, (b) the use of a grid-square system that can also provide a basis for measuring distance or range, and (c) the use of a system where the various areas coextensive with the major terrain features are the basic units. Each of the systems has been used in previous work. Mathematical formulas and the grid-square system have been applied extensively by many nations to war gaming and map exercises for many years. A recent ORO technical memorandum[5] discusses an application of system c.

Each of the three systems for computing terrain effects has certain advantages and disadvantages in the present case depending on (a) the scope of the military problems to be investigated, (b) the types of electronic computers available, (c) the type of weapon performance data available, and (d) the facility with which the same methodology handles other battle factors such as communications, training, and tactical doctrine.

A choice among these systems is made by identifying the one that best meets the requirements of the methodology when stated in the above terms. To make this identification requires that specific instances of the application of

these systems be considered. Other sections of the memorandum show that frequent reference to the terrain features by one of these methods is required for two general purposes: First, influence on movement, which is subdivided into (a) determining the trafficability of terrain over which the combat element is moving or is considering movement, (b) determining the degree of cover and concealment (referred to enemy positions) offered by the terrain over which the combat unit is moving or is considering movement, and (c) control of the general maneuver so that progress toward the terrain objectives results.

Second, influence on firing, which is subdivided into (a) identifying those enemy units which are not visible, or only partly visible, owing either to their defiladed position (intervening terrain features cut off the line of sight) or to the concealment afforded by the vegetation surrounding the enemy combat unit, and (b) determining the range between combat units.

These purposes may be reduced to two general requirements: (a) the significant terrain features that characterize the actual position (or a proposed future position) of the combat unit must be known, and (b) the visibility of a remote enemy unit from the position of any given combat unit must be known. The best system will be the one that yields acceptable approximations in the least computing time.

Mathematical Formulas

As an example of the application of conventional formulas to the coding of terrain features for the computer, consider the following simplified case. A tank is moving across an area open except for a large tree stand. The speed

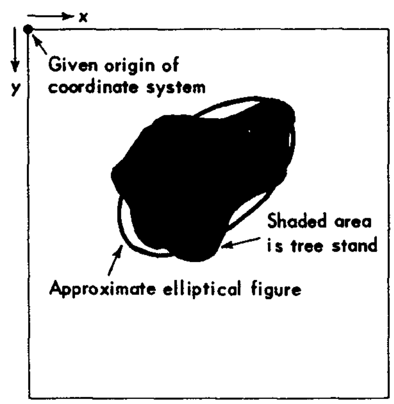


Fig. B1—Approximating the Perimeter of a Tree Stand on an Open Plain by an Elliptical Figure

For the approximate elliptical figure the equation is

$$x^2 + cy^2 + dxy + ex + fy + g = 0$$

The coefficients c, d, e, f, and g are adjusted for the best approximation

with which the tank moves depends on whether it is within or without the tree stand. The computer must therefore be provided with directions permitting the determination of this fact. The current grid coordinates of the tank are known to an accuracy of ±1 m.

To apply the system of mathematical formulas requires that the perimeter of the tree stand be approximated by an equation. A simple approximation is to fit an ellipse to the perimeter (Fig. B1). Annex B1 shows how the computer may determine for any position of the tank whether it is within or without the tree

stand. To do this requires that five constants be stored in the computer to define the equation for the elliptical figure. The calculations require seven multiplications. If more than one ellipse were required to yield an acceptable approximation to the perimeter of the tree stand, then additional constants, five for each ellipse, would have to be stored in the computer and, on the average, three to four additional multiplications would be required for each added ellipse.

Before considering the other factors that were stated above to characterize the three systems, each of the other two systems will be applied to the same example.

Grid-Square System

Application of the grid-square system by the computer in order to determine whether the tank is within or without the tree stand is straightforward. Before the computations are started, the entire battle area is divided up into a system of grid squares (Fig. B2).

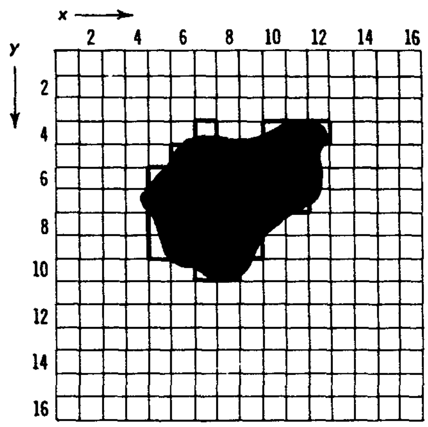


Fig. B2—Approximating the Perimeter of a Tree Stand (Shaded Area) on an Open Plain by the Grid-Square System (Heavy Lines)

In order to be able to determine, for an arbitrary position of the combat unit, whether it is within or without the tree stand it is necessary for the computer first to identify the grid square including the combat unit's position and then to refer to data previously stored in the computer, which gives the desired information. Figure B3 gives a flow diagram for accomplishing this. By measuring the position coordinates in units of the length of one side of a grid square, the coordinates of the grid square including the position of the combat unit are found by ignoring their fractional parts.

The flow diagram in Fig. B3 accomplishes the same determination as does the flow diagram in Fig. B7 of Annex B1, yet involves no multiplications. All the operations together involve only the equivalent of approximately one-fourth of a

multiplication time. Therefore the grid-square determination is, for the case of one tree stand in an open plain, computed at least 16 times as quickly compared with the use of an elliptical approximation, provided that no significant time is lost while the computer searches through the memory to locate the proper constants. The most important gain, however, results from the fact that, although additional multiplications are required as the number of tree stands increases, when using approximating formulas, no increase in computation time results as the number of tree stands is increased when using the grid-square system.

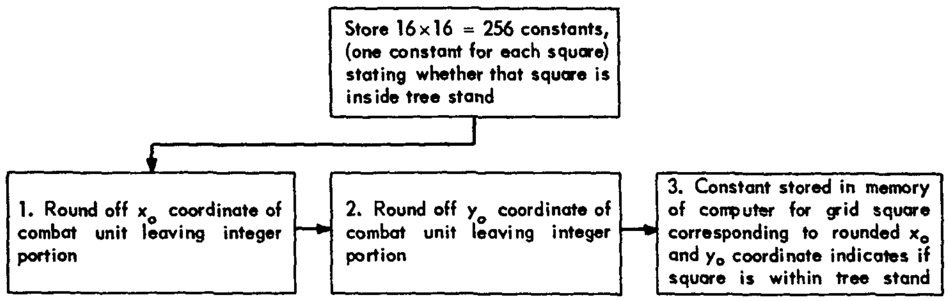


Fig. B3—Flow Diagram Showing Calculations to Determine Whether Combat Unit Is Inside or Outside Tree Stand (Fig. B2) Using Grid-Square System

Thus, if there were five separate tree stands, the grid-square system would permit determination whether a combat unit was within or without a tree stand at least 40 times as quickly as the formula system would.

The disadvantage of the grid-square system is the much larger number of constants that must be stored in the computer before the calculation is started. The flow diagrams in Figs. B3 and B7 show that, although the formula system requires only five constants to be stored, the grid-square system requires the storage of 256 constants to supply the same information. Thus, in general, the large savings in calculation time the grid system provides is only acquired at the cost of an increased demand on the memory capacity of the computer.

In general the same compromise obtains everywhere in the computer battle. Virtually every separate action during the battle can be speeded up significantly when a grid-square system is used but only at the expense of the capacity of the memory and only if data in the memory can be located quickly.

System of Terrain-Feature Areas

In contrast with the formula system and the grid system, this method does not include at any time an accurate specification of the position (x and y coordinates) of the combat unit. The position of the combat unit is known only in terms of the terrain-feature area it is within. The problem of determining which terrain-feature area includes the combat unit never arises. The problem the computer is concerned with is to cause the combat unit to move from one terrain feature to another in a sensible manner. Since the exact position of any combat unit within the area coincident with the terrain feature is not known, the range from the combat unit to some other combat unit cannot be accurately determined. To the extent that particular weapons effects (which depend on range) must be

included, this is a serious disadvantage. However, the system does permit concentration on an element that is very prominent in any statement of tactical doctrine, i.e., the relation between the military effectiveness of a combat unit and the terrain feature it occupies. For a more detailed discussion of this system, refer to the memorandum previously mentioned.[5]

Comparison of Systems

A preliminary discussion of the relative desirability of the three systems for inserting terrain features into a computer is now possible. This discussion is in terms of three of the four factors previously listed: (a) type of military problem, (b) type of computers available, and (c) type of weapon performance data available. (The fourth factor, treatment of other battle factors, is taken up in the section "Tactical Doctrine," of this appendix.)

The nature of presently available weapon performance data (e.g., from the proving grounds) rules out the third system for the immediate purposes of this methodology, since the method does not include specific reference to the range separating combat units. Thus, insofar as the killing power of weapons as a function of range is a primary measure of effectiveness of weapon systems, such data cannot be included directly in a calculation using the third system.

Table B1

DESIRABLE COMPUTER FEATURES FOR THE TWO PRINCIPAL SYSTEMS OF CODING TERRAIN FEATURES

Computer feature	Emphasis required for system	
	Formulas	Grid squares
Size of memory	Not emphasized	Very large
Access to memory	Not emphasized	Very fast
Speed of multiplication	Very fast	Not required
Speed of addition	Not emphasized	Emphasized
Special operations	Not required	Emphasized

Both of the remaining systems do include some reference to the position of a combat unit. Hence the range to some other combat unit can be computed, permitting use of weapons effectiveness data, which has a strong dependence on range.

A choice between the remaining two systems can be made tentatively on the basis of which will better exploit the capabilities of the best modern computers for rapid calculation. It will be recalled that the grid-square system of calculation was the more rapid (compared to the use of formulas) when the memory of the computer was large enough to store the much larger number of constants, and provided that the computer was able to locate desired constants rapidly in this memory. Also the use of formulas requires the computer to perform numerous multiplications, whereas the grid-square system uses only the simpler operations such as addition.

It is therefore reasonable that, since computers usually compromise one or another of their capabilities in favor of emphasizing some other capability, there would be, among all available computers, one that would perform best with the formula systems and a second that would perform best using the grid-square system. Which of these two "system-computer" combinations is the better for simulating battle is not obvious a priori.

However, at present general-purpose high-speed computers tend to differ mainly in the size of their memory and to perform multiplications much more slowly than additions. General-purpose computers seem to be best suited for battle simulation work—owing to the great flexibility in their use. Tentatively then, the grid-square system appears most attractive, in which case the most desirable feature of a computer to be used for battle simulation is a large memory. Table B1 summarizes the desirable features of a computer in terms of the preceding discussion.

Application of Grid System to Maneuver

Limitation of Grid System. Unlike the formula system, the grid-square system cannot be used to indicate accurately the position of small terrain features. For example, a small clump of vegetation may offer important concealment to a combat unit. But if the clump is smaller than a single grid square, its exact position within the square cannot be designated. As a consequence, only movement from one square to another can be related directly to the terrain features. So far as the calculations are concerned, every position within a square is influenced in the same way by the average terrain features of the whole square.

It follows that in general the only meaningful option available to a combat unit is the selection of an adjacent grid square to be presently occupied.

Also, if the grid-square system is used to measure the range between units, then this range cannot be specified more accurately than the size of the grid square permits.

Mixed Systems. It is not essential that only one of the several systems be selected for codifying the terrain features. Nevertheless a mixed system would be expected to take a longer time for calculation. None was considered for this feasibility study. However, it may well be that some critical action within the battle requires a special treatment, and some loss in speed can be tolerated.

A possibility in this regard is the action of small infantry groups. Thus, whereas a knowledge of the range between tanks to the nearest 100 yd may be sufficient for most cases, the range to nearby infantry groups may sometimes require refinement to within only a few yd.

There are three important qualifications to be added: First, the utility of the grid-square system regarding other battle factors must be taken into account. Second, as the memory capacity of the computer is applied to various grid-square calculations, eventually the residual memory capacity will be insufficient to support additional grid-square calculations, forcing dependence on the use of formulas. Third, new developments in computers may so facilitate multiplication operations as to tip the balance in favor of the extensive use of formulas.

KILL PROBABILITIES

Much the same series of alternatives, as was available in the coding of terrain features, applies to the storing of kill-probability data for the various combat elements. The principal alternatives are (a) to store formulas from which the kill probability can be computed, or (b) to store extensive tables providing separate entries for all variations in range, target type, type of shooter, etc., which are adjudged significant. Again the formula system is characterized by (a) the requirement to store only a few constants that define the equation, and (b) calculation of any given kill probability using an equation which is apt to involve numerous time-consuming multiplications.

On the other hand, although the use of tables of kill probabilities avoids lengthy calculations, the extensive tables require a large memory capacity. A special advantage of tabulated kill probabilities is the ease with which irregular or nonuniform kill probabilities may be included. Thus, once set up for the use of tables, no new formulas need to be designed and inserted into the coding to take account of newly proposed weapon characteristics.

Again, as the memory capacity of a computer approaches exhaustion, there may come a time when there is no room for the tabulated kill probabilities required for some special circumstance. Such a situation might force the use of formulas for special cases.

The battle code used in this memorandum affords an example of such a case. The kill probabilities of an infantry squad of fractional strength f are found by multiplying the kill probability of the full-strength squad, stored in table form, by the factor f.

TACTICAL DOCTRINE

Actual battle involves (a) physical weapons and their performance characteristics, (b) the maneuver of weapon systems wherein the human weapon operators are very prominent, and (c) a codified set of principles—tactical doctrine—which serve as guidelines to the unit commanders as they develop their plan of action (or concept). To be of use, a tactical doctrine must be stated in such general terms as to permit application to a variety of specific combat situations; i. e., it cannot be too specific.

Thus a battle model must be capable of implementing the general type of rules—or axioms—that are the substance of an element of tactical doctrine.

The three systems of introducing terrain features have been briefly discussed in terms of the facility with which they treat of weapons (e.g., range dependence) and weapon systems (e.g., terrain objectives). A final choice must, however, depend also on their facility in implementing tactical doctrine.

A statement of an element of doctrine is a (tentative) identification of a course of action depending on the relation between such elements as a covered approach, fields of fire, built-up enemy position, military crest, and ratio of forces. All these elements involve, directly or indirectly, areas on the battlefield of various shapes and sizes to which such statements can be applied; e.g.,

this area is within the enemy fields of fire; that area provides a covered approach to the enemy position; the ratio of forces in this area is 2 to 1. It follows that implementation of a tactical doctrine with a battle simulator requires that such areas be easily identified during the course of a battle (or just preceding the battle). Thus the discussion of terrain-feature areas in the previous sections applies here. The formula system involves lengthy calculations whenever areas of arbitrary shape and extent are considered. The grid-square system avoids such lengthy calculations if the computer has a large memory capacity. The terrain-feature area has as its basic elements the very areas required to implement (and discover!) elements of a tactical doctrine.

EVALUATION OF GRID-SQUARE SYSTEM

Clearly the terrain-feature-area system is favored by the ease with which it deals with the type of statements—the building blocks—used in formulating a tactical doctrine. Unfortunately this system does not also provide in a convenient way the means for including weapon characteristics. Thus the grid-square system appears to be a usable compromise between the requirement that the system can handle weapon performance characteristics and the elements of a tactical doctrine.

Table B2

RELATIVE ADVANTAGES AND DISADVANTAGES OF THREE SYSTEMS OF CODING TERRAIN FOR A COMPUTER

System	Best suited for what type of analysis	Suited for what type of computer	Fits presently available weapon performance data	Fits other factors in battle
Formulas	Weapons	Limited-memory general-purpose computer	Very well	No
Grid squares	Maneuver of weapon systems	Large-memory general-purpose computer	Well	Fair
Terrain-feature areas	Tactical doctrine	Special logical computer	No	Very well

Table B2 summarizes the discussion of the merits of the three systems. If one of the three systems is to be chosen, it appears that the grid-square system is the best compromise.

On the other hand it might be expected that improved battle codes are possible if the best elements of all three systems are combined in a mixed system.

LINE-OF-SIGHT CALCULATIONS

An essential step in the firing calculations requires that it be known which of the opposing combat units are visible to the combat unit preparing to fire. The grid-square method of calculating this is indicated in Fig. 10. An important alternative in the design of the battle refers to the possible desirability of carrying

out this extensive calculation for all possible positions of the combat units in advance of the battle calculations themselves. If the memory capacity of the computer is sufficient to contain all the results of such a calculation, and if the results once stored are readily available for use, then significant savings in the time to compute a large series of battles on the same terrain are possible.

In this feasibility study it proved possible to store the results of this precalculation in the memory since the Red combat units were confined to a region embracing only 96 of the 100-m grid squares. Thus, by using each bit in the 24-bit numbers to indicate whether or not a "line of sight" did exist between a pair of grid squares, the results of the precalculation required only 2304 numbers* for storage, which was well within the 16,000-number capacity of the 1101 drum. However, if the Red combat units had not been confined to only a portion of the battlefield, then it would have required a minimum of three times this number of words of storage, or 6900 words. Further, if the data were required to be easily accessible, then six times this amount (13,800 numbers) is required. Owing to the quantity of other data also required, this would have been impossible.

If any significant variation in the system is made, precalculation of the line of sights between grid squares may become unfeasible. In any such case it will be necessary to consider the desirability of an increased number of grid squares as opposed to the cost in time of carrying out line-of-sight calculations. This last depends on the particular capabilities of the computer to be used but also on the nature of the terrain and the tactics to be used by the opposing forces since the calculations are drastically reduced if the combat units spend any appreciable amount of time in heavy cover or concealment.

It may be expected that optimum solutions of this time-saving problem will in general involve a combination of precalculations plus calculations during the battle itself for special or unusual circumstances. This in turn suggests that grid squares of nonuniform sizes may find future application.

FLEXIBILITY VS SPEED

If a logical scheme of calculation is to be used, an important pair of alternatives in the manner used to carry out that calculation occurs.

As an example of such a pair of alternatives, consider a logical operation, necessary whenever one combat unit (e.g., a tank) must choose a single target from among a group of possible targets (e.g., several enemy tanks). To make such a selection the computer must be supplied with a priority list stating all the rules necessary to eliminate as a target all the enemy tanks but one. The pair of alternatives arises from the existence of two extreme methods of implementing such a priority list. After the nature of the two methods, respectively, these alternatives are identified as implicit logical calculation and explicit logical calculation.

Implicit Logical Calculation

In an implicit logical calculation the priority system to be used is rigidly fixed by the particular sequence in which the computer carries out the calculation. Suppose for example that there are three different types of enemy

*Number words = (576 squares × 96 squares)/(24 pairs / number) = 2304 numbers. If economy in storage space had been sufficiently important, this could have been reduced to 2082 numbers. However, access to the data would then have been much more time consuming.

tanks: type A, type B, and type C. Suppose further that the desired priority system is as follows:

Priority 1: Always select type A as a target when the group of available targets includes this type. If there is more than one such tank, select one at random.

Priority 2: If there are no type A tanks, then select a type B tank if present; if more than one such tank, select one at random.

Priority 3: If there are no type A or type B tanks in the group of available targets, select any type C tank at random.

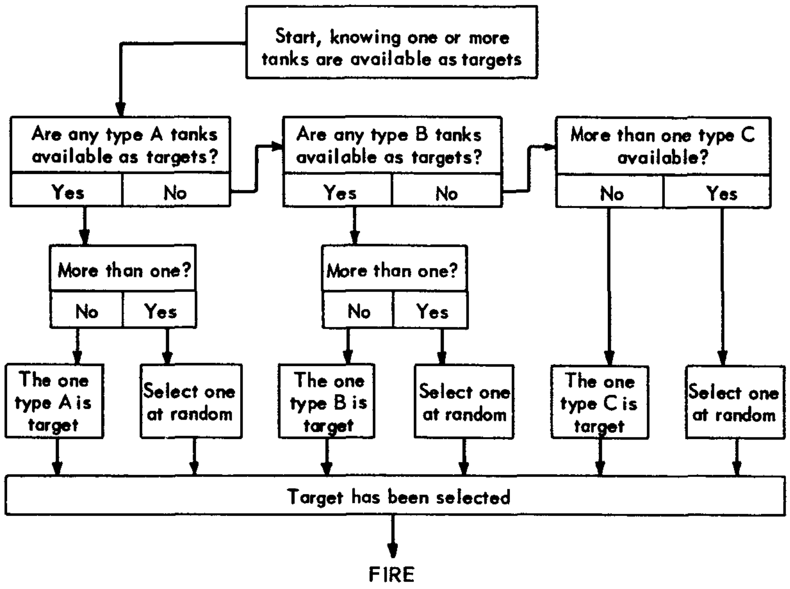


Fig. B4—Flow Diagram That Implements Implicit Priority System Governing Selection of Target

A sequence of operations permitting the computer to select a target under this priority system is illustrated by the flow diagram in Fig. B4.

The important characteristic of this flow diagram is that nowhere does it indicate that type A tanks have first priority. Type A acquires first priority only because of the order in which the various operations are performed, i.e., the priority system is implicit not in what the orders say but rather in the order in which they are performed.

This is the system used in the present battle to implement the priority systems used in selecting a target. The computer used can carry out such a sequence of operations at great speed.

The disadvantage of this system is that the only feasible way of changing the priority system is to make the necessary changes in the entire series of basic orders used to code for the computer. This can be a very time-consuming operation.

Explicit Logical Calculation

This system of logical calculation has characteristics opposite to those of the implicit type. Whereas the previous method is carried out very quickly, this one is done rather slowly; however, whereas the previous system allows new priority systems to be added only with great difficulty, the explicit system permits rapid modification.

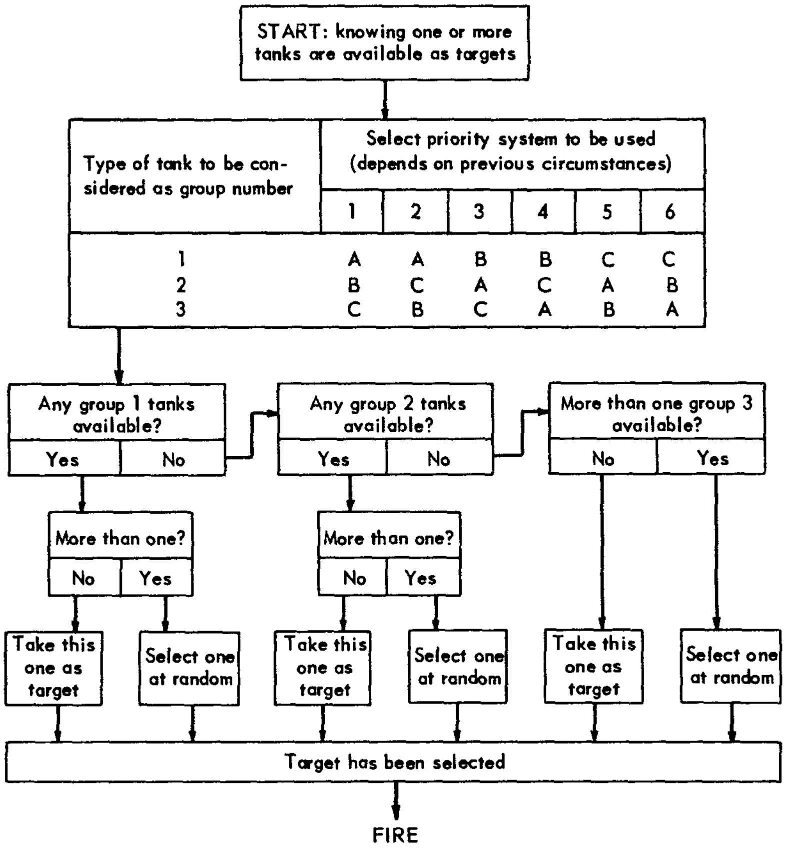


Fig. B5—Flow Diagram That Implements Explicit Priority System Governing Selection of Target

A flow diagram for an implicit logical calculation can easily be altered to serve for explicit calculation. (The system of orders required for the computer to implement the flow diagram will, in general, be much more complicated.)

To modify the flow diagram in Fig. B4 for explicit calculation is straightforward. The modified flow diagram is shown in Fig. B5.

The scheme of logical calculation illustrated permits any one of the six possible priority systems involving three types of tanks to be used. Changing

from one system to another is effected by selecting the appropriate priority system number. Once set up, no modification in the numerous basic orders used to control the computer is required.

Choice between Methods

Essentially all the logical computations used in the computer battle could be set up for either method. A choice in each case is a compromise between the desirability of speed and economical use of the memory capacity (favors the implicit system) and the desirability of flexibility (favors explicit system).

Owing to the limited capacity of the 1101 computer most of the logical calculations for the battles computed in this study were set up using the implicit system. The much larger 1103 computer, which can be used for application of the computer battle methodology, will permit extensive use of the more flexible explicit system.

Annex B1

DETERMINATION OF POSITION RELATIVE TO TERRAIN FEATURES COMPUTED BY FORMULAS*

It is to be determined, using conventional mathematical formulas whether a given point x_o, y_o, which represents the coordinates of a combat unit, is within or without a terrain feature whose perimeter is approximated by an ellipse with major axis 2B, and minor axis 2A; whose center is at x_1, y_1; and with the major axis inclined by an angle θ to the x axis (Fig. B6).

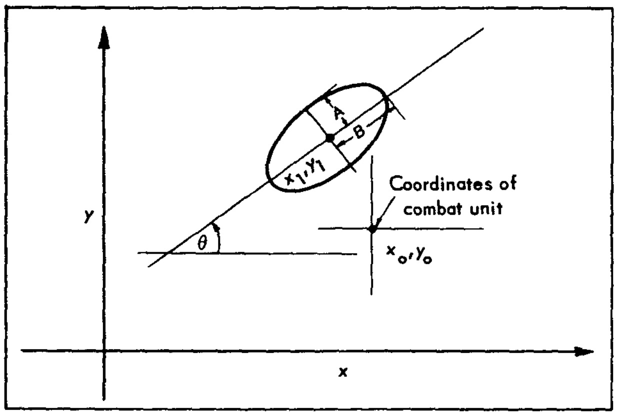


Fig. B6—Parameters Defining an Arbitrary Ellipse Used to Approximate the Perimeter of a Terrain Feature

$$h(x,y) = x^2 + ay^2 + bxy + cx + dy + e = 0$$

where
$$a = 1/f(B \sin^2 \theta + A \cos^2 \theta)$$
$$b = 1/f[(B^2 - A^2) \sin 2\theta]$$
$$c = 1/f(-2x_1 f - y_1 b)$$
$$d = 1/f(-x_1 b - 2y_1 a)$$
$$e = 1/f(x_1^2 f + x_1 y_1 b + y_1^2 a - A^2 B^2)$$
$$f = B^2 \cos^2 \theta + A^2 \sin^2 \theta$$

The point x_o, y_o falls within the area if and only if

$$h(x_o, y_o) \leq 0.$$

The flow diagram describing the determination of whether the point x_o, y_o is within the ellipse is shown in Fig. B7.

*As suggested by R. Durfee (ORO).

Inspection of Fig. B7 will show that a total of seven multiplications are required to carry out the complete calculation. If more than one such area is involved, then the same routine must be repeated for each such area until the point is shown to be in one of them, or in none of them. On the average, therefore, this operation must be repeated a number of times at least as great as one-half the number of ellipses since, if the areas are mutually exclusive and taking the excluded area as an additional area, then the point is just as likely to be in one ellipse as in any other.

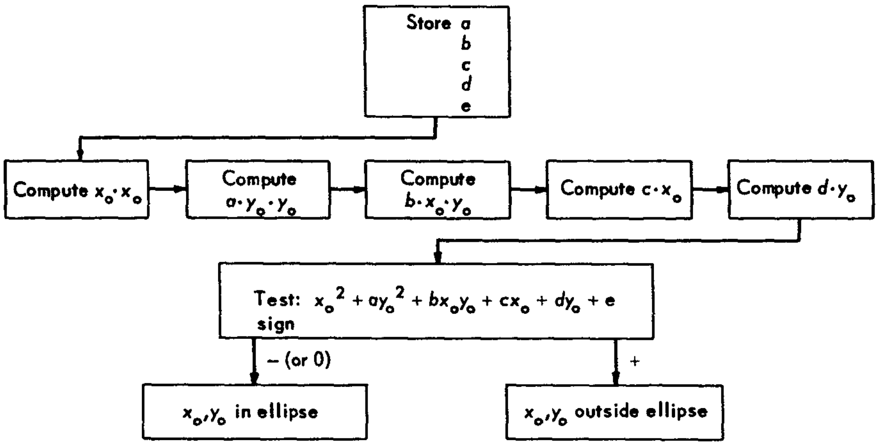


Fig. B7—Flow Diagram to Determine if Combat Unit at x_o, y_o Is Within Arbitrary Ellipse: $x^2 + ay^2 + bxy + cx + dy + dy + e = 0$

On general-purpose digital computers, the time to carry out a multiplication is about five times as long as is required for additions, subtractions, and "test for inequality." Hence only the multiplications in the subroutine need be considered when estimating the time required for calculation.

CONCLUSION

Use of generalized ellipses to locate a combat unit with respect to n terrain features will generally require between $\frac{7}{2}n$ and $7n$ multiplications each time the point is located with reference to the ellipses. Five constants must be stored for each ellipse included.

Appendix C

DETAILS OF COMPUTER BATTLE

CONTENTS

Appendix C

DETAILS OF COMPUTER BATTLE

CONTENTS

CONTENTS (CONTINUED)

INTRODUCTION

In this appendix all the militarily significant operations that are the subject of computation during the battle are described. The detailed flow diagram, which lists the operations and the order in which they are performed, is followed by a running commentary on the diagram. Then four sections present all the performance characteristics used for the battle. These include the various kill probabilities, see probabilities, speed of movement, and move probabilities.

Finally the two different formats used by the computer in presenting the results of a battle are described.

DESCRIPTION OF DETAILED FLOW DIAGRAM

Figure C1 is the flow diagram showing each militarily significant step in the calculations. About 100 different steps are indicated in the various major operation boxes. To carry these out requires about 7000 separate orders to the computer. A list of these 7000 orders is not given in this memorandum. Appendix A lists the basic orders used by the computer in carrying out these calculations as well as an example of their application to the target selection operation.

Start Routine

S1 This group of orders sets up the initial values required to start a battle. For example, if the computer has just finished one battle and is ready to start another, then all the dead tanks must be revived; the locations in the computer that record the number of rounds expended by moving tanks must be set back to zero; etc.

S2 This group of orders assembles the line-of-sight data, which apply to the combat units in their starting positions. To do this it uses the same group of orders, M21, which are used by the moving routine throughout the entire battle to assemble the same data.

Clocks Routine

C1 This group of orders searches through the clocks of all units and identifies that clock which has the lowest time "on" it. This has the next turn and will be carried through the computer routine.

C3, 4, 5 This group of orders makes a test each time a unit is chosen to move, to determine whether the first 15 min of the battle are up (C3). C4 sets up all the firing clocks, except the moving Blue units, to within

a random amount of 3 sec of the battlefield time shown on the unit being processed. C5 then sets C2 permanently to the B position, bypassing this test for the rest of the battle.

C6 This operation is a check to determine whether the $\frac{1}{2}$-hr limit on battles is up. If so the computer goes into the repeat routine. If not, the computer continues the calculations.

C7 This operation determines whether the clocks routine selected the mortar battery to fire. If it did, the computer turns next to the barrage routine. Otherwise it goes to the writing routine.

Barrage Routine

B1 These orders select a square at random from the 800- by 1200-m area containing the Red units.

B2, 3 These orders check to see if there is a Red infantry unit on the square. If so their effectiveness is reduced by the appropriate factor as determined from the table of kill probabilities (Annex C1, Table C16).

B4 B4 resets the firing clock of the mortars and records the results of these computations. Control is returned to the clocks routine.

Writing Routine

W1, 2 This group of orders establishes which clock was chosen by the clocks routine and therefore whether the unit is to be processed by the moving routine or the firing routine. It then sets up the order sequence for the computer in the manner required for processing the particular unit chosen. A complete list of all the preparations made in the writing routine will not be given at this time. A study of the firing and moving routines themselves is necessary to understand such a list. For example, if the unit has been selected as ready to fire its main armament again, then the unit's selection of a target depends partly on whether the unit knows that it has been fired at. Every time a unit is fired at during the firing routine, operation F29 decides whether the target shall be aware of that fact. If the decision is to so inform the target, then the memory is so adjusted. The way in which this is actually done is to record the fact that the writing routine will choose the "yes" exit path from operation F8 when that target itself is selected to fire.

In describing other operations in the various routines, reference is not usually made as to whether the operation makes use of the writing routine. It will generally be clear from the context whether the operation is to be done only for some specified unit when that unit is treated next, or whether the operation will henceforth affect every unit, thus being carried out immediately and permanently without involving the writing routine.

Firing Routine

F1, 2 In this group of orders each unit selected to fire first identifies those enemy units which have been picked up before and are still visible. This requires the use of a "line-of-sight" word (S_1) with a "have-seen" word (S_2). Combined, these give the units previously seen which are still visible. The dead tank units are then removed from this list, using the "dead" word S_3. F2 then checks to see whether this calculation has produced any potential targets. The section "Target Identification" in App A describes this operation in detail.

F3–F7 If the above routine does not produce any targets then this group of orders allows the unit an opportunity to "survey" the battlefield, with a view toward picking up a target. Since this process must take time, the only thing accomplished by this group of orders is, at most, to select one or more targets which the unit will be able to take under fire after the required time delay. To do this, the memory is first checked to determine whether any unit has disclosed its position. If there are such, then F4 gives those units a 0.5 chance of being added to the "have seen or heard of " memory of the target seeker. After this, F7 computes when the unit will be given a chance to fire again, using a constant time delay (30 sec) plus a small random number of seconds, totaling between 30 and 62 sec. If no units have disclosed their positions, then F3 goes to F5, where it is determined whether there is a line of sight from the unit to any enemy units. If there is not, then F7 is used as before to reset the firing clock. If there is a line of sight to one or more enemy units, then F6 gives the target seeker a 0.5 chance of seeing each of them, and those seen are added to the unit's "have seen or heard of" memory. Finally the code proceeds to F7, where the fire clock is reset as described above.

F8–F17 If the group of orders F1, F2 does produce some possible targets from previous knowledge, then this group of orders is used to add to the list certain special targets of high priority and to make a choice among all targets so as to take one of them under fire. The routine actually adds to the list and implements a priority system at the same time. Therefore the most compact way in which to describe the effect of this group of orders is to give the priority system applied. It is as follows:

Priority 1. Return fire of visible tank known to be firing at target seeker. The knowledge of being fired at comes from F21 (computed in F10, F11, and F12).
2. Continue firing at last tank target (F14 and F15).
3. Make a random choice on all visible tanks (F17).
4. Return fire of infantry unit (F11, F12, and F13).
5. Continue firing at last infantry unit (F14, F15, and F16).
6. Random choice of visible infantry units (F17).

F18, 19 At this point it is determined whether the target selected is a new target. If so then the F18 switches to F19. This later group of orders is used to delay firing on a new target until sufficient time has elapsed

for the turret to be swung around and the gun laid on the new target. In the present routine the delay is taken to be a constant 8 sec. (Since the unit must be processed again by the target selection process before it is actually allowed to fire at the selected target, there is a chance that a target of higher priority will interrupt before fire is actually delivered.) F19 terminates the firing calculations and control is returned to clocks.

F20 In F20 the firing routine is set up for the actual firing, in the event the selected target does not require any delay for switching the turret and laying on the target. The correct kill probability is selected from tables held in the memory. To do so the computer refers to all the information describing the shooter, target, range, whether moving or stationary, influence of partial cover, etc. All the other information required has been stored during the computations and must be inspected. For example, M25 may have decided that the shooter is stationary and the target is moving, which will affect the kill probability.

F21 F21 calculates when the unit will be able to fire the next time, although the firing clock will not actually be reset till the end of firing routine, in F33. The reset time is, of course, a function of what type of unit (tank or infantry) is firing, and includes a small random number, distributed uniformly between certain limits. For a medium tank the total will be between 11 and 19 sec with an average of 15 sec. This group of orders also keeps track of the ammunition expenditure of the moving tanks, and, if the shot being processed is the last round of the tank, it is prevented from firing ever again, by setting its firing clock up to a very large value that can never be reached during the battle. In any event the firing routine continues to process the present shot.

F22–F25 This group of orders determines whether there has been a kill when the target is a tank (F25) and reduces the effectiveness of the target when the target is an infantry unit (F23). F24 takes into account the reduced kill probability required when an understrength infantry unit is the shooter. To compute this, the kill probability from the tables is multiplied by the fractional effectiveness of the unit.

F26 F26 records the results when a tank is killed and checks to see whether the battle is over by reason of all the tanks on one side being dead. In that event the computer proceeds to the repeat routine.

F27, 28 This group of orders carries out two operations: First, F27 takes note of the first tank casualty (either side) and, by changing M8, thereafter the moving routine is caused to check whether there are any dead tanks in any of the squares to which a unit is considering moving. Second, F28 sets up the Red moving clocks by a small random amount each time a Red unit is killed. Since the Red move clocks are originally set to a very large time, they will never be selected to move until this setting-up operation has been repeated enough times to lower

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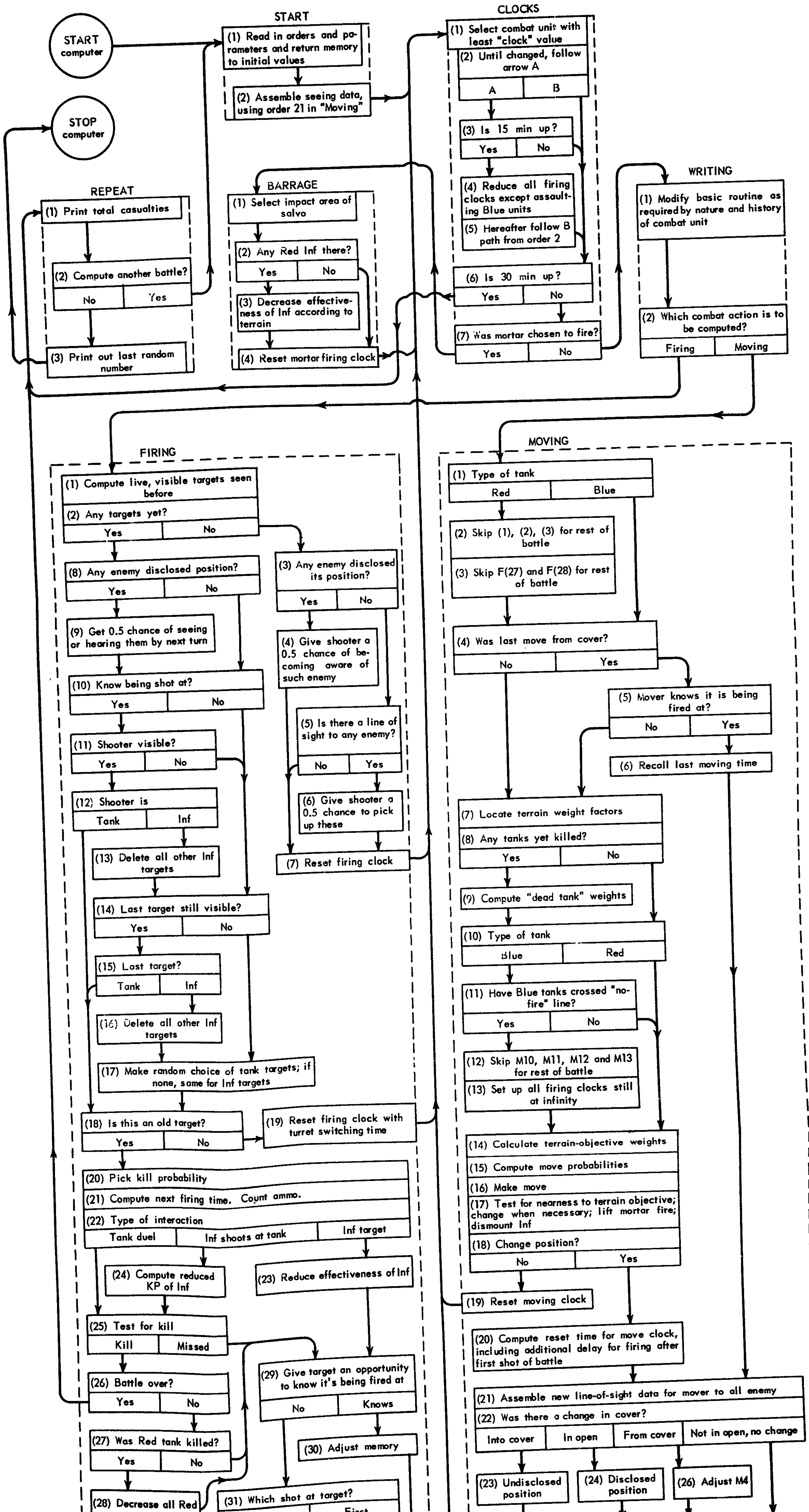

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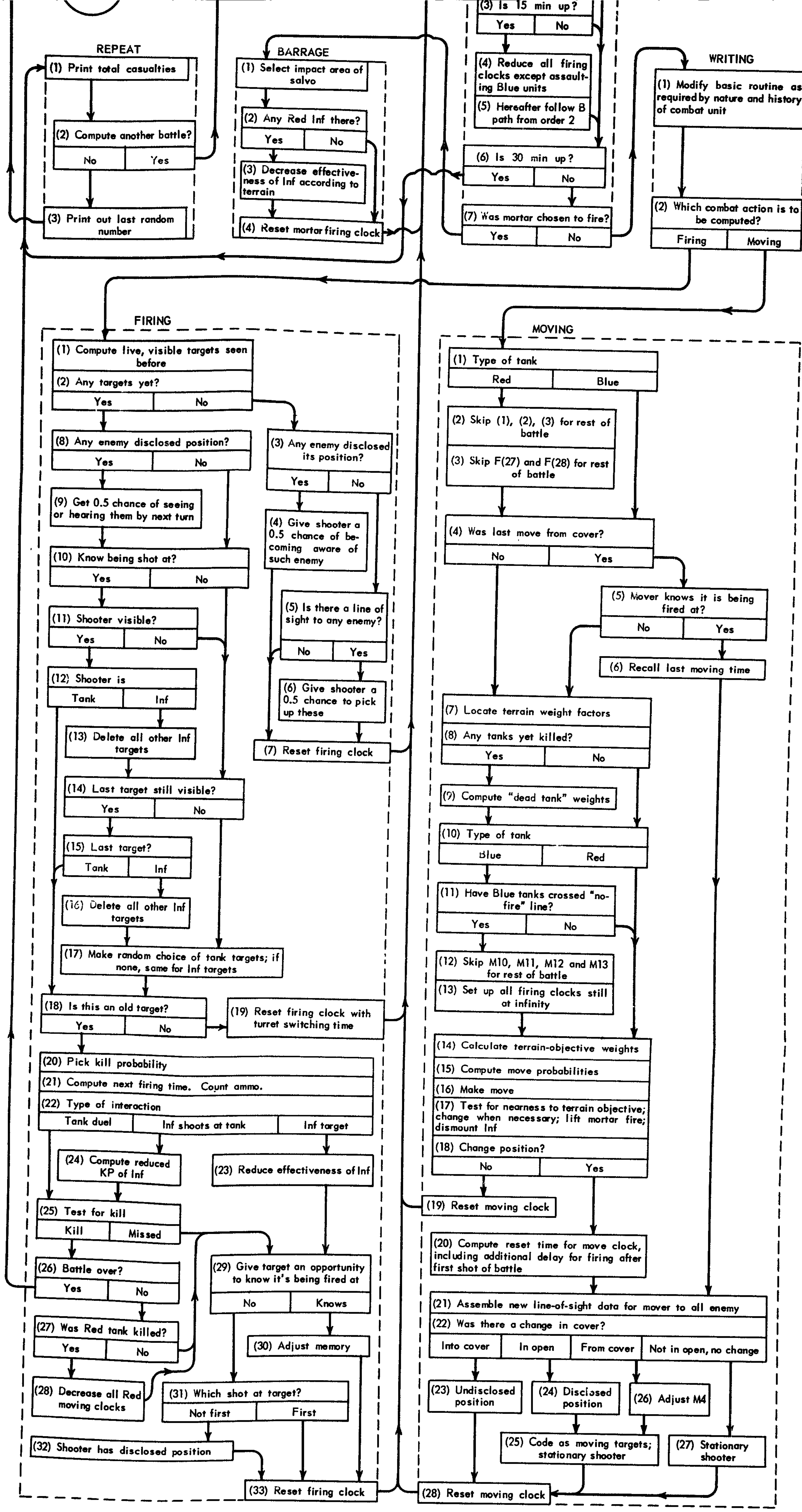

Fig. C1—Detailed Flow Diagram

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the clock value on one of the Red units to a point where the clocks routine selects it for moving. As soon as one Red unit has been selected to move, M3 changes F27 so that the Red move clocks are no longer set up for each Red casualty.

F29–33 Every unit allowed to fire goes through this last group of orders. F29 decides whether the target will become aware that it is being shot at. This is done even though the target has been killed, since, if the choice is to let the target know it is being fired at, F30 is used to include the shooter in the "disclosed-position" memory. The effect of this is to give the shooter the same chance of disclosing its position for the battlefield as a whole as it has of disclosing its position to the target it is shooting at. The probabilities used in this routine are given in Table C1. (See Annex A3 for the way in which these probabilities are combined with the other logical operations.)
In the course of making known the fact that a target is under fire, F30 sets M5 to "yes," F10 to "yes," and adds the shooter to the list of units the target has seen or heard of. These three orders have a practical effect only if the target was not killed. From this point the computer proceeds to F33 where the firing clock for the shooter is reset using the time calculated by the order group F20 already described. In the event that F30 decides not to let anyone know that

Table C1

PROBABILITY OF DISCLOSING POSITION
TO TARGET AND ALSO BEING PUT IN
DISCLOSED-POSITION MEMORY

Probability	Range intervals, m	
	Inf target	Tank target
1.00	0–100	0–500
0.50	100–200	500–1000
0.25	200–1500	1000–1500
0.125	1500 and over	1500 and over

the shooter was firing at the target, then the computer proceeds to F31, where, if this is the second or later shot fired from the same position, the shooter is definitely added to the list of units that have disclosed their position. Finally the computer goes to the last operation as before (F33) and resets the firing clock.

Moving Routine

There are only two possible outcomes of this computation; either the unit changes its position (exit from order group 28) or it does not (exit from order group 19).

M1, 2, 3 This group of orders stops F28 from effecting further reductions in the Red moving clocks as soon as any Red tank is selected to move. Since all the Red move clocks are set down, on the average, about the same amount, as soon as any one Red move clock is low enough to be selected by clocks, the others will not be far behind. M3 causes the use of this group of orders to be canceled for the remainder of the battle.

M4, 5, 6 This group of orders checks whether the "emergency move" is called for. This move is used by a combat unit in the special case when (a) it has just moved from cover and (b) it knows that it has been fired at; then it automatically chooses to return to the covered position. M6 causes this return move to consume the same additional time as had elapsed since the move from cover. If the emergency move is called for, M6 bypasses M7 through M20.

M7, 9, 15, 16 This group carries out the move calculations proper; i.e., the move probabilities are determined. M7 assembles the precalculated ratings of each adjacent square as they depend on the terrain features of that square alone. The ratings used in the present battle are given in

Table C2

VALUES USED TO WEIGHT SQUARE ON BASIS OF ITS TERRAIN FEATURES

Weighting values	Concealment	Special terrain features	Weighting values	Concealment	Special terrain features
	Normal			Crest of Hill (continued)	
+15	Three-quarter		− 5	Full	Forest
+13	Half		+15	Half	Edge of forest
+11	Quarter		+ 5	Zero	Trail
+ 9	Zero			Steep Hill	
− 5	Full	Forest	+10	Three-quarter	
+13	Half	Edge of forest	+ 8	Half	
+ 9	Zero	Edge of swamp	+ 6	Quarter	
−15	Zero	Swamp	+ 4	Zero	
+15	Zero	Trail	−10	Full	Forest
	Crest of Hill		+ 8	Half	Edge of forest
+15	Three-quarter		+ 4	Zero	Edge of swamp
+15	Half		+10	Zero	Trail
+15	Quarter		−13	1 or more tank casualties on square	
−10	Zero				

Table C2. M9 modifies the local terrain ratings, computed in M7, according to whether there are any tank casualties in the vicinity. In the present battle a square containing one or more tank casualties is penalized 13 points. No test is made for the color of the tank casualty in this battle since, during most of the fighting, tanks of opposite colors do not occupy the same general area.

The last probability factor used in computing the move depends on the direction of the terrain objective. Each adjacent square is rated on this basis, using the scheme described in Fig. C3 and under "Terrain Objective." Application of this system results in a high rating for the square in the direction of the terrain objective, a large negative rating for the square directly opposite to the terrain objective, and intermediate ratings for the remainder of the adjacent squares.
M15 then combines the three separate ratings for each square, resulting in a single over-all rating for each adjacent square. Interpreted as probabilities, M16 then uses these ratings to make a "Monte Carlo" choice among the nine possibilities.

M11 M11 keeps the Blue assaulting tanks and infantry from firing until at least one of their number has penetrated east into the north-south band composed of all squares whose x coordinate is 17. In the event this occurs before 15 (battlefield) min have elapsed then none of the combat units are yet firing, in which case M11 will start all units firing.

M12 M12 causes the computer to skip the calculation in M11 once a combat unit has crossed the no-fire-line.

M17 M17 checks on whether a given combat unit has approached its current terrain objective closely enough to require substituting the next terrain objective for future calculations. In the battle computed here the actual location of the first terrain objective for each assaulting combat unit is several thousand yd east of the Red position. However, the terrain objective is changed several thousand yd north of the Red position as soon as each Blue unit reaches the neighborhood of the actual Red position. This was done for mathematical reasons. The effect of these calculations is the same as if the terrain objectives were actually in the Red positions. The system is described in detail in the section "Terrain Objective." The mortar fire is stopped as soon as any one combat unit approaches the first terrain objective so closely as to require a change in the axis of advance. Also the infantry squads are caused to dismount from their armored carriers at this point. The practical effect of this change is to substitute an altered set of "kill probabilities." There is no change in the moving calculations.

M18, 19 Here the computer checks on whether the preceding calculations resulted in a change of position. If there was no change in position, then, since no adjustments of the memory are necessary, the moving calculations terminate with M19 and control is returned to clocks.

M20 Using the terrain of the selected square, the time delay required for the necessary movement is computed using the data in Table C3, and includes an additional time, which varies between 0 and 32 sec. Included is a correction for the extra distance involved when the combat unit has selected one of the "corner" squares (Fig. C2).

M21 As a result of each move, all the line-of-sight information previously assembled into the line-of-sight memory word relating to the moving unit and each enemy unit must be corrected for the new position. Since line-of-sight calculations were made for every necessary pair of squares before the battle commenced, this operation involves only

Table C3

ASSUMED SPEEDS OF MOVEMENT OF ALL UNITS

Tank speed, mph			Terrain	Concealment
Medium (and all other units)	Light	Heavy		
2	4	1.0	No hill	Three-quarter
3	6	1.5		Half
4	8	2.0		Quarter
5	10	2.5		Zero
1	2	0.5	Forest	Full
3	6	1.5	Edge of forest	Half
5	10	2.5	Edge of swamp	Zero
0	0	0	Swamp	Zero
15	20	5.0	Road	Zero
1.0	2	0.5	Steep hill or crest of hill	Three-quarter
1.5	3	0.8		Half
2.0	4	1.0		Quarter
2.5	5	1.3		Zero
0.5	1	0.3	Forest	Full
1.5	3	0.8	Edge of forest	Half
6.0	12	3.0	Road	Zero

sorting out from the memory the results of the line-of-sight precalculation for the particular squares occupied by the combat units involved. Once sorted out, these data are combined into a single large "number," which is used in the firing calculations until another move occurs.

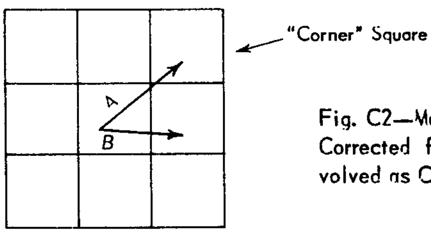


Fig. C2—Movement to "Corner" Square Is Corrected for the Longer Distance Involved as Compared to Movement Along B

M22–28 This group adjusts the "disclosed-position" information about the moving combat unit according to the nature of the change in concealment resulting from the move. Also decided is whether the unit shall be considered stationary or moving if it becomes involved in a shooting action. Finally the move clock is reset with the value previously computed in M20 and control is returned from M28 to clocks.

Repeat Battle

R1 This group of orders causes the final data to be printed out. This is actually the total number of Red tanks killed and the total number of Blue tanks killed.

R2 These orders check on whether the computer is to compute another battle. If so then the computer stores the last random number (which is used by the computer to start off the next battle) and control is returned to start where another battle commences.

R3 If the computer is not to compute another battle, R3 causes the computer to type out the last random number and stop operation.

CONTENTS OF MEMORY

The content and nature of the computer battle is only partly indicated by a flow diagram showing the order in which the important operations are performed. Appendix B gives a discussion of the importance of the information stored in a computer's memory when logical calculations are involved. Therefore as a necessary companion to the detailed flow diagram discussed in the previous section, the general nature of the computer's memory contents is described.

Of the 16,384 numbers (or "words") in the computer's memory, roughly 7000 are required to direct the operations of the computer. The remaining 9000 numbers are used mainly for the storage of information. Appendix A discussed the special (binary) number system used by the computer for these purposes.

Table C4 gives the principal data stored in the memory of the computer.

FIRING PERFORMANCE CHARACTERISTICS

Kill Probabilities

All the kill probabilities used in the trial calculations are given in the eight tables in Annex C1. They are not directly supported by experimental data, since, at the time of calculations there were no data taken under the necessary field conditions. Since that time Project STALK (BRL and OCAFF) results have become available and seem to meet some of the requirements for such data. In the absence of valid experimental data, the various kill probabilities were estimated, based on unpublished theoretical calculations made available by V. V. McRae and M. Grabau of ARMOR Group (ORO). For purposes of these feasibility calculations it is not necessary that the assumed kill probabilities have high accuracy. However, before such computer battles can be put to their most efficient use, improved data related to the proper field conditions will be required.

The entries in the tables are the kill probabilities expressed as a fraction, with the number indicating the number of sixteenths that most closely approximate the true kill probability. This is the form in which the computer most easily handles the data. A higher accuracy was not deemed necessary in these calculations, but can be imposed when required.

Table C4

PRINCIPAL DATA STORED IN COMPUTER MEMORY

Memory locations required	Data	Remarks
467	Kill probabilities	Contents Table C9 to C16; six kill probabilities are stored in each word
2304	Precalculated line of sight	Results in terrain precalculation and each of the 24 bits in a word is associated with one pair of squares; it is a 1 if there is a line of sight between that pair, a 0 otherwise
576	Local terrain weights	One word is used for the rating each square receives by virtue of the local terrain features; values used are given in Table C2
48	Terrain objectives	The assaulting combat units can be provided with nine successive and distinct terrain objectives; data stored are the coordinates of the grid square for each terrain objective; also included are the alternative firing positions provided for the defending Red forces
2	Dead word	One memory location is used by each of the two forces to keep a record of which tanks have become casualties; the bit in each of the 24 positions is a 1 or a 0 according to whether the associated combat unit is yet a casualty; since the Blue forces have only 20 combat units, 4 of the positions in the Blue dead word are not used
44	Have-seen-or-heard-of word	Each combat unit uses one such word to keep a record of which enemy units it has seen or heard of; "heard" implies it was advised by the communication system of the whereabouts of the enemy unit; the bit in each of the 24 positions in the number is a 1 if the associated enemy combat unit has been detected, a 0 otherwise
44	Line-of-sight word	Each combat unit uses one such word to keep current the record of all enemy units on a terrain square that can be seen by the unit; the bit in each of the 24 positions is a 1 if the associated enemy combat unit can be seen, a 0 otherwise
2	Disclosed-position word	Each of the two forces uses one of these words; the bit in each of the 24 positions is a 1 if the associated combat unit has been deemed to have disclosed its position, either by moving across an open space or firing repeatedly; it is a 0 otherwise
18	Mobility	These memory units contain the constant time delay to be used in setting up the move clock for motion across a particular terrain type of square; it does not include the correction necessary when motion is along a diagonal
89	Clocks	Each combat unit uses one of these words to retain the future time when it will be able to fire again and a second word serving the same purpose for future moves; there is also a firing clock for the mortars
44	Position	Gives the x and y coordinate of the current position of the combat unit
132	Firing counter	Each combat unit uses one of these to keep a running total of the total number of shots fired; another for the total shots fired from the same position; and a third for the total number of rounds fired at the same target
12	Infantry strength	One of these words is used for each of the 12 infantry squads in the battle to keep a record of its current strength
	Miscellaneous constants	In general, one word is used to retain the value used for each of the many constants: e.g., the 15-min delay before firing; the no-fire line of x = 17; the time limit of the battle (1800 sec); the maximum value of the x and y coordinates (24); the time delay required when a tank must swing its turret to a new target

The lowered kill probabilities applied to the first round, when the target is partly concealed, are meant to account for a lack of exact knowledge of the position of the target tank, which is sometimes the case when a target tank has fired from a concealed position.

The kill probabilities calculated for the light tank are patterned after the M41 light tank; those for the heavy tank after the T43 heavy tank. The infantry capability against tanks assumes the use of rocket launchers fired at approximately 30-sec intervals at ranges of not over 100 m.

The kill probabilities of infantry against infantry and tanks against infantry are assumed to take account of small-arms fire, mainly machine-gun, lumping together these effects at roughly 30-sec intervals. These kill probabilities are also cut off at 100 yd in these calculations. The kill probabilities against infantry units are not actually used in a probability sense. Instead the effectiveness of the infantry unit is reduced by a factor equal to the kill probability. If by repeated hits an infantry unit is reduced in effectiveness below one sixteenth, it is taken as totally destroyed.

It was further assumed for purposes of this trial calculation that the infantry mounted in carriers would be assumed to move with great caution, and that hence they would not present a target to enemy antiarmor weapons over 100 yd distant; i.e., the enemy AT weapons were given a 0 kill probability whenever they were separated from the Armd Pers Carr by one or more intervening squares. A different set of kill probabilities is used according to whether the Blue infantry are inside or outside their carrier. In both cases, however, the infantry effectiveness is degraded by the kill probability factor, rather than totally destroyed.

Since a moving tank was not assumed to have a significant capability against other tanks, no entries are made in the tables for this circumstance. However, the machine guns on a moving tank are assumed to have an anti-infantry capability.

To a first approximation it was assumed that the larger size of a T43 canceled out the advantage of the somewhat heavier armor compared to the M48. Hence the kill probabilities of the enemy armor against the T43 and M48 were taken to be the same.

Each of the tanks were assumed to be firing the best ammunition known to be available to it, either HVAP or APC.

Rates of Fire

The time delays to be associated with firing are of three kinds: (a) delays while turret is traversed and gun laid on new target—8 sec, (b) delays before a combat unit is given a new opportunity to acquire a target whenever the firing calculations are terminated owing to the lack of a target—average 46 sec with a probability uniformly distributed between 30 and 62 sec, and (c) delays for all combat units before firing a second or later shot against the same target (given in Table C5).

Ammunition Supply

The infantry units, mortar battery, and stationary tanks in the battle are permitted an inexhaustible ammunition supply. The last are the SU-100 Red tanks and the seven overwatching Blue tanks in each action. The moving tanks

are limited to their base load of ammunition. Once this ammunition is expended, the moving tanks can no longer fire during the battle. Table C6 gives the assumed quantities for these base loads.

Table C5

RATES OF FIRE, ALL COMBAT UNITS

Combat unit	Time delay, sec			Average rounds per minute
	Minimum	Average	Maximum	
Blue mortar battery	0	32	64	2 (salvos)
Blue medium tank	11	15	19	4
Blue light tank	6	10	14	6
Blue heavy tank	26	30	34	2
T-34	11	15	19	4
SU-100	11	15	19	4

Table C6

BASE LOAD OF AMMUNITION
FOR MOVING TANKS

Tank	Rounds
Blue medium tank	60
Blue light tank	60
Blue heavy tank	30
T-34	60

<u>No-Fire-Line and Time</u>

The limitations on firing effected by the no-fire-line of $x = 17$ and the time limit of 15 min before any of the units (except the mortars) are allowed to fire are not strictly meaningful in the military sense. These restrictions were imposed mainly to reduce the time of calculation so as to permit the calculation of a larger number of battles within the budgetary limits. They should not be interpreted as performance characteristics.

MOVING PERFORMANCE CHARACTERISTICS

In the following subsections are listed all the numerical values which were assumed for the performance characteristics of the combat units relating to movement. The breakdown of the contour map into squares and the list of terrain features to be associated with these squares are given in Figs. 8 and 9. The mathematical treatment of these parameters is illustrated by a sample move calculation in Annex C2.

Mobility Factors

Table C3 gives the speeds of movement that the various combat units were assumed to have, according to the character of the terrain over which they are moving at the time. These numbers permit the computer to calculate the number of seconds the move clocks must be advanced to allow time for the combat unit to move to its new position. The computer selects the speed corresponding to the terrain features of its new position. The longer distance to be associated with a move diagonally across the grid lines is taken into account by multiplying the time delay computed for an east-west or north-south move by the factor sec 45 deg = $\sqrt{2} = 1.41$.

To the time delay computed from the mobility alone is added a variable time, varying uniformly between 0 and 32 sec with an average value of 16 sec. This variation may be adjusted to account for variations among tank crews.

Firing by Assaulting Tanks

After the assaulting Blue tanks have passed the no-fire-line they begin firing. Thereafter a correction factor must be applied to the time of arrival at the next position computed from the mobility factors just discussed. This correction factor allows for the time lost by the assaulting tanks when they stop to fire. To take account of this, 64 sec is added to the computed time delay. This is approximately sufficient for the tank to stop and fire 2 rounds in the course of its movement to the next position.

Weight Factors for Computing Move Probabilities

In the present battle all moving tanks are assumed to use the same system of weights for computing the move probabilities to be associated with each of the neighboring squares and the current position of the tank. Table C2 gives the weights used for taking account of the terrain features and also the presence of a tank casualty.

Terrain Objectives

The weight assigned to a square to account for the direction toward the terrain objective is a variable number and is computed by the method shown in Fig. C3. For purposes of comparison with the values given in Table C2, Fig. C4 shows the values of the terrain-objective weight factor on each of the eight neighboring squares for two extreme positions of a Blue assaulting tank.

All assaulting Blue tanks are given the same theoretical terrain objectives. Initially it is at 23,09. As it approaches to within 400 m in the east-west direction and, simultaneously, to within 400 m in the north-south direction, each Blue tank has its theoretical terrain objective changed. This criterion is equivalent, except in special situations, to designating the military objective of the assaulting Blue tanks as a north-south line of grid squares 800 m long, starting at 18,05 and extending south to 18,13.

The second theoretical terrain objective given to the assaulting Blue tanks is at 20,00. This grid square does not actually exist on the map. However, the same 400-m criterion already mentioned is used again. Thus the north-bound assaulting Blue tanks need only reach the east-west line of grid

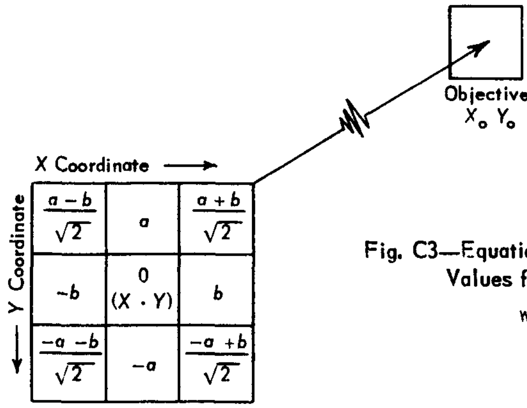


Fig. C3—Equations for Calculating the Weighting Values for Each Adjacent Square

Where $a = |Y_o - Y|$
$b = |X_o - X|$

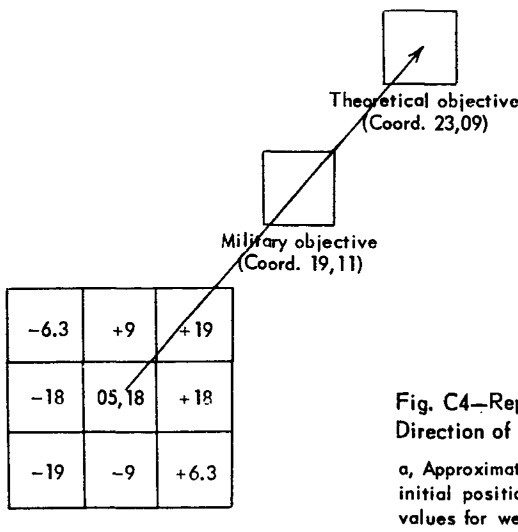
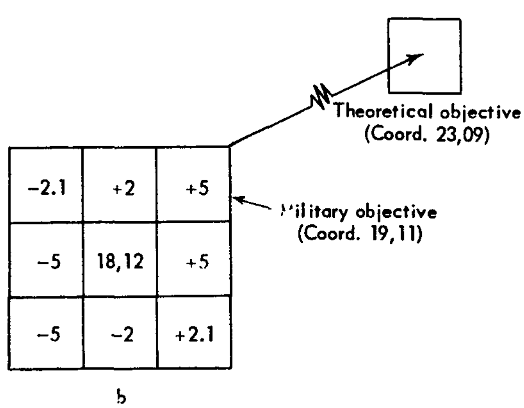


Fig. C4—Representative Weights Computed to Account for Direction of Terrain Objective Using Method in Annex C2

a, Approximate maximum values for weight factor: Blue tank in initial position, coordinates (05,18); b, approximate minimum values for weight factor: Blue tank, at coordinates (18,12) is one square away from military objective



squares running from (16,04) to (24,04) to have their terrain objectives changed once more.

In the present battle, the battle is usually halted before any combat units have approached the second objective. However, the code provides for a sequence of nine distinct terrain objectives. For purposes of this code the above two objectives are simply repeated, alternately.

Table C7

POSITIONS FOR RED MOVING TANKS AND INFANTRY

A. First Alternate Position for Particular Red Moving Tanks and Infantry

Combat unit		Alternate position coordinates
T-34 no.	33	20,08
	34	19,04
	35	22,04
	36	20,12
	37	20,09
	38	19,05
	39	20,10
	40	18,11
	41	19,08
	42	20,12
Infantry squad no.	48	23,03
	49	19,08
	50	21,04
	51	22,06
	52	21,10
	53	20,12
	54	19,05
	55	22,04
	56	22,04

B. Secondary Alternate Positions for All Red Moving Tanks and Infantry

Objective[a]	Alternate position coordinates
2d	21,04
3d	23,06
4th	18,05
5th	21,12
6th	18,05
7th	21,04
8th	21,12
9th	18,05

[a]Alternate position.

The primary alternate positions to which the moving Red combat units are caused to move when they begin taking heavy casualties are treated as terrain objectives. Table C7 gives the coordinates of these primary alternate positions.

As each Red moving combat unit reaches its primary alternate position it is assigned additional alternate positions as listed in Table C7. In the present battle the calculations rarely reached a stage where these additional alternate positions came into use.

OTHER RESTRICTIONS AND PERFORMANCE CHARACTERISTICS

Length of Battle

The restriction on the length of the battle (30 min) was, in part, arbitrary. It was selected partly on the basis of budgetary considerations. The battle

itself was designed to cause heavy (approximately 50 percent) casualties to be suffered within the time limit so as to show clearly variations in the effectiveness of the combat units.

For 7 of the 21 heavy tank battles the battle was permitted to continue for an additional $4\frac{1}{3}$ min to compensate for the slowness with which the heavy tanks approached the enemy position.

For the last 14 of the heavy tank battles, the length of the battle was again restricted to 1800 sec. To speed up the computations the heavy tanks were permitted to move more rapidly during the approach before the shooting commenced. During such a period, when there is no firing, the scale of time is arbitrary and speeding up the movement does not affect the results.

Communications

The influence of the communications system on the progress of the battle is included in an approximate fashion. This results from two calculations, both of which involve the sharing of information concerning the existence and position of enemy units among several friendly combat units. These two calculations are (a) the operations F4, F6, and F9 (Fig. C1), which give a combat unit a 0.5 chance to become aware of the existence of an enemy tank that has disclosed its position by an overt action of movement (across an open field) or firing; and (b) the operation M5 (Fig. C1), where the choice of movement depends on whether a combat unit is aware it is being fired at. M5, in turn, depends in part on F32. Each of these operations assumes that the combat unit can become aware of the existence of an enemy combat unit either by observing that unit or by receiving a communication from another (friendly) combat unit. Thus the correct probability required for these calculations must include the effectiveness of the communication system.

Enemy Area

Throughout the battle the Red elements are restricted to an area 1200 by 800 m in extent. The squares in this area are on the interior of the rectangular area at 17,02, 24,02, 17,13, and 24,13. This restriction has the effect of reducing drastically the number of pairs of squares for which the line-of-sight calculation had to be made and the quantity of results to be stored in the computer. It can be relaxed when the more capacious computers now available are used.

Initial Clock Settings

At the start of the battle all move clocks of the assaulting Blue tanks are set to 0, and a time to the nearest $\frac{1}{64}$ sec selected at random from the interval of 0 to 3 sec is added into each move clock. This serves to give every combat unit an equal chance at the start of each battle of being selected first, second, third, etc., for its first move. The time is computed to such an accuracy, not because it is known to have a real significance, but to establish an order of moving with a negligible chance for ties to develop.

Initially all firing clocks (except the mortar) are set at a very large value to prevent firing. As soon as the operation C3 or M11 (Fig. C1) determines that (some) firing should commence, the firing clocks of all appropriate com-

bat units are first set at the then current battlefield time (i.e., the same time as the move clock of the combat unit then being processed), and then to each is added a (different) time selected at random from the interval 0 to 3 sec. This serves to give every eligible firing unit an equal chance of being selected first, second, third, etc., to begin firing activities.

At the start of the battle all the move clocks of the Red moving tanks (T-34) are set to a very high value. Thus, unless these clocks are reduced, the T-34's will not be selected to commence movement toward their alternate positions. However, each time a Red tank becomes a casualty, F27 reduces every Red move clock by variable times selected at random from the interval 0 to 4 min. Thus as the battle proceeds and additional Red tanks become

Table C8

INITIAL POSITION OF ALL COMBAT UNITS

Forces	Moving vehicles			Stationary vehicles			Infantry squads	
	Unit	Code	Coord	Unit	Code	Coord	Code	Coord
Blue	Tank	01	02,18	Tank	11	02,05	26	06,23
		02	03,18		12	02,04	27	04,18
		03	05,18		13	03,03	28	05,18
		04	04,18		14	05,07		
		05	04,20		15	06,23		
		06	05,18		16	01,11		
		07	04,18		17	02,04		
		08	06,23					
		09	07,20					
		10	07,23					
Red	T-34	33	17,05	SU-100	43	20,07	48	20,08
		34	17,04		44	21,04	49	23,03
		35	20,07		45	20,08	50	23,07
		36	20,07		46	18,10	51	20,07
		37	23,04		47	20,09	52	21,04
		38	23,07				53	20,05
		39	23,06				54	23,06
		40	21,04				55	20,09
		41	20,05				56	18,10
		42	23,03					

casualties the Red move clocks are reduced to progressively lower (but different) times. Eventually one of these move clocks reaches a value so low that it is selected to move. At that point this reduction calculation is suspended. Thereafter the Red tanks are selected by the clocks operation for movement on the same basis as are the assaulting Blue tanks. Since the Red move clocks were reduced by variable amounts, they will not all commence moving at the same time.

Initial Position of Combat Elements

Table C8 gives the coordinates of the initial positions of all the combat units in the battle. (See Fig. D1 in App D). The mortar battery has no specified position.

FORMAT FOR RESULTS

Only a limited quantity of results of the battle can be typed out by the ERA 1101 computer during battle computations without seriously delaying the computations. However, there will be a continuing requirement that the detailed progress of selected battles be available for study. To meet this requirement for each battle the computer is caused to record the progress and results of each battle in two distinct forms: a short form and a long form.

Short Form (Casualty Data)

The computer types out directly on a single line the major items of interest relating to each casualty at the time of its occurrence. The following data are indicated:

(a) The letter r or b depending on which side suffered the casualty.
(b) The code number of the combat unit that became a casualty (2 digits).
(c) The time, to the nearest sec, when the casualty occurred (3 to 4 digits).
(d) The position coordinates of the combat unit that became a casualty (3 to 4 digits).
(e) The letter r or b and the code number of the combat unit causing the casualty (1 letter and 2 digits).
(f) The position coordinates of the shooter (3 to 4 digits).
(g) If the casualty were a tank, the number of consecutive rounds fired to produce the casualty (1 or 2 digits) or if the casualty were an infantry unit, the numerator of a fraction with a denominator of 16 that gives the remaining effectiveness of the combat unit (1 or 2 digits).
(h) The letter and code number of any tank that runs out of ammunition before the next casualty is recorded (1 letter and 2 digits).

For example, when the computer types out the following two lines:

r37	247	20,7	b11	11,5	3	r39
b27	253	22,4	r41	22,3	8	

then the occurrence of two casualties is indicated with one additional tank running out of ammunition. Specifically the first line indicates that red tank, code number 37, was killed at 247 sec, when at position x = 20, y = 7, by blue tank, code number 11, at position x = 11, y = 5, by the third consecutive round. The last element of this first line, r 39, indicates that red tank, code number 39 ran out of ammunition at some time during the 6-sec interval before the occurrence of the casualty indicated by the second line. The second line indicates the blue infantry squad, code number 27, was hit 253 sec after the battle started, when at the position x = 22, y = 4, by red tank, code number 41, while at position x = 22, y = 3; and that the infantry unit was reduced in effectiveness to eight-sixteenths of its full strength by this hit The absence of any entry in the last column of this line indicates that no tank ran out of ammunition before the time of the next casualty.

Long Form (Moving or Firing Actions)

During the calculation of the battle the computer causes a detailed record of each combat action to be recorded in the form of a specially coded punched paper tape. This tape is many feet long for a complete battle. In order to

make the data stored on this tape intelligible, it must be run back through the computer. The computer then deciphers the pattern of holes punched in the tape and causes the associated typewriter to type out one line of data for each separate moving or firing calculation effected during the battle. With present equipment this operation is very time consuming, taking about three times as long as the original battle calculation; i.e., about 1 hr.*

The typewritten record of the combat actions computations is arranged to provide one line for each action. The five different possible actions are:

(a) unit moved to new position,

(b) unit considered movement but rejected it and remained in the same position,

(c) unit fired at enemy unit and missed,

(d) unit fired at enemy unit and hit, and

(e) unit had an opportunity to fire but failed to do so, either because it had no target or had to delay firing while traversing its turret.

As an example of the form used for each of these five cases, samples of each are arranged in the accompanying tabulation in the same order as in the preceding paragraph.

Column

1, 2	3	4	5, 6	7
b09	0124.36	15,07		
b01	0126.07	nc		
r36	0139.25		b09	
r36	0172.10		b09	Yes
r36	0205.64		nsf	

The first line indicates that Blue tank 09 at 124.36 sec moved to square 15,07. (The square from which it moved would be found by checking the preceding move.) The second line indicates that Blue tank 01 at 126.07 sec considered moving but decided against it (nc = no change in position). The third line indicates that Red tank 36 at 139.25 sec fired at Blue tank 09 and missed. The fourth line indicates that Red tank 36 at 172.10 sec fired at Blue tank 09 and (yes) killed it. (The short form tells which consecutive round this was.) The fifth line indicates that Red tank 36 at 205.64 sec did not accept an opportunity to fire (nsf = no shot fired.)

In the present battle each battle involves the calculation of about 1600 separate combat actions. About 1200 of these are for the trivial case when dismounted infantry are fired on at long range with machine guns having 0 kill probability. The remaining 400 significant combat operations involve movement and firing calculations where the kill probabilities are not 0.

*Improved equipment is now available to speed up this process enormously.

Annex C1

TABULATED KILL PROBABILITIES

Table C9

RED INFANTRY KILL PROBABILITIES FOR ANY SHOT
(Probabilities to nearest sixteenth; i.e., 15 ≡ 15/16)

Target	Target movement	Range, m	Concealment of target: Zero	Quarter	Half	Three-quarter	Full
Any Inf	Moving	0	15	11	8	6	3
		100	6	3	1	0	0
	Stationary	0	5	2	1	0	0
		100	0	0	0	0	0
Med tank	Moving	0	4	4	4	4	4
		100	2	2	2	2	2
	Stationary	0	8	8	4	4	4
		100	4	4	4	4	4
Light tank	Moving	0	5	5	5	5	5
		100	3	3	3	3	3
	Stationary	0	9	9	5	5	5
		100	5	5	5	5	5
Heavy tank			Same as medium tank above				

Table C10

BLUE INFANTRY KILL PROBABILITIES FOR ANY SHOT[a]
(Probabilities to nearest sixteenth; i.e., 8 ≡ 8/16)

Target	Target movement	Range, m	Concealment of target: Zero	Quarter	Half	Three-quarter	Full
Red Inf	Moving	0	8	5	4	3	2
		100	3	2	1	0	0
	Stationary	0	5	2	1	0	0
		100	0	0	0	0	0
T-34 and SU-100	Moving	0	4	4	4	4	4
		100	2	2	2	2	2
	Stationary	0	8	8	4	4	4
		100	4	4	4	4	4

[a]Regardless of state of motion of Blue Infantry.

Table C11

BLUE MEDIUM TANK (T48) KILL PROBABILITIES
(Probabilities to nearest sixteenth; i.e., 2 ≡ 2/16)

Target	Shot	State of motion		Range, m	Concealment of target				
		Shooter	Target		Zero	Quarter	Half	Three-quarter	Full
Red Inf	1 or n	Moving	Stationary	0	2	1	1	1	1
				100	2	1	1	1	1
	1 or n	Stationary	Stationary	0	2	1	0	0	0
				100	2	1	0	0	0
	1 or n	Stationary	Moving	0	4	2	1	1	1
	1 or n	Moving	Moving	0	2	1	1	1	1
T-34	1	Stationary	Stationary	0–500	14	11	7	4	0
				500–1000	10	8	5	3	0
				1000–1500	6	5	3	2	0
				1500–2500	3	2	2	1	0
	n	Stationary	Stationary	0–500	14	14	14	14	0
				500–1000	13	13	13	13	0
				1000–1500	10	10	10	10	0
				1500–2500	6	6	6	6	0
	1	Stationary	Moving	0–500	13	8	2	1	0
				500–1000	10	6	2	1	0
				1000–1500	7	4	1	1	0
				1500–2500	3	2	1	0	0
	n	Stationary	Moving	0–500	14	14	14	14	0
				500–1000	10	10	10	10	0
				1000–1500	5	5	5	5	0
				1500–2500	2	2	2	2	0
SU-100	1	Stationary	Stationary	0–500	14	11	7	4	0
				500–1000	8	6	4	2	0
				1000–1500	5	4	3	1	0
				1500–2500	2	2	1	1	0
	n	Stationary	Stationary	0–500	14	14	14	14	0
				500–1000	11	11	11	11	0
				1000–1500	8	8	8	8	0
				1500–2500	5	5	5	5	0

Table C12

BLUE LIGHT TANK KILL PROBABILITIES
(Probabilities to nearest sixteenth; i.e., 13 = 13/16)

Target	Shot	Motion of target	Range, m	Concealment of target			
				Zero	Quarter	Half	Three-quarter
Red Inf		Same as Blue medium tank against Red Inf, Table C11					
T-34	1	Stationary	0–500	13	10	6	3
			500–1000	10	8	5	3
			1000–1500	5	4	2	1
			1500–2500	2	2	1	1
	n	Stationary	0–500	14	14	14	14
			500–1000	12	12	12	12
			1000–1500	9	9	9	9
			1500–2500	5	5	5	5
	1	Moving	0–500	12	9	5	2
			500–1000	8	6	4	2
			1000–1500	2	1	1	0
			1500–2500	1	1	0	0
	n	Moving	0–500	14	14	14	14
			500–1000	9	9	9	9
			1000–1500	4	4	4	4
			1500–2500	1	1	1	1
SU-100	1	Stationary	0–500	13	10	6	3
			500–1000	8	6	4	2
			1000–1500	4	3	1	1
			1500–2500	2	1	1	0
	n	Stationary	0–500	14	14	14	14
			500–1000	12	12	12	12
			1000–1500	8	8	8	8
			1500–2500	4	4	4	4

Table C13

BLUE HEAVY TANK KILL PROBABILITIES
(Probabilities to nearest sixteenth; i.e., 14 = 14/16)

Target	Shot	Motion of target	Range, m	Concealment of target			
				Zero	Quarter	Half	Three-quarter
Red Inf	Same as Blue medium tank against Red Inf, Table C11						
T-34	1	Stationary	0–500	14	11	8	5
			500–1000	10	8	5	3
			1000–1500	7	6	4	3
			1500–2500	5	4	3	2
	n	Stationary	0–500	14	14	14	14
			500–1000	13	13	13	13
			1000–1500	12	12	12	12
			1500–2500	8	8	8	8
	1	Moving	0–500	13	10	7	3
			500–1000	8	6	4	2
			1000–1500	4	3	2	1
			1500–2500	2	2	1	0
	n	Moving	0–500	14	14	14	14
			500–1000	10	10	10	10
			1000–1500	7	7	7	7
			1500–2500	4	4	4	4
SU-100	1	Stationary	0–500	14	11	8	5
			500–1000	10	8	5	3
			1000–1500	7	6	4	2
			1500–2500	4	3	2	1
	n	Stationary	0–500	14	14	14	14
			500–1000	12	12	12	12
			1000–1500	10	10	10	10
			1500–2500	7	7	7	7

Table C14

T-34 KILL PROBABILITIES
(Probabilities to nearest sixteenth; i.e., 7 ≡ 7/16)

Target	Shot	Motion of target	Range, m	Concealment of target				
				Zero	Quarter	Half	Three-quarter	Full
Dismounted Inf	Same as Blue medium tank against Red Inf, Table C11							
Mounted Inf	1	Stationary	0–100	7	5	4	2	0
	n	Stationary	0–100	7	7	7	7	7
	1	Moving	0–100	7	5	4	2	0
	n	Moving	0–100	7	7	7	7	7
Blue medium tank (also Blue heavy tank)	1	Stationary	0–500	14	11	7	4	0
			500–1000	8	6	4	2	0
			1000–1500	3	2	2	1	0
			1500–2500	1	1	1	0	0
	n	Stationary	0–500	14	14	14	14	0
			500–1000	11	11	11	11	0
			1000–1500	8	8	8	8	0
			1500–2500	4	4	4	4	0
	1	Moving	0–500	13	10	7	3	0
			500–1000	6	5	3	2	0
			1000–1500	1	1	1	0	0
			1500–2500	0	0	0	0	0
	n	Moving	0–500	14	14	14	14	0
			500–1000	8	8	8	8	0
			1000–1500	2	2	2	2	0
			1500–2500	1	1	1	1	0
Blue light tank	1	Stationary	0–500	14	11	7	4	0
			500–1000	9	7	5	3	0
			1000–1500	4	3	3	2	0
			1500–2500	2	2	1	0	0
	n	Stationary	0–500	14	14	14	14	0
			500–1000	12	12	12	12	0
			1000–1500	9	9	9	9	0
			1500–2500	5	5	5	5	0
	1	Moving	0–500	13	10	7	3	0
			500–1000	8	6	4	3	0
			1000–1500	1	0	0	0	0
			1500–2500	0	0	0	0	0
	n	Moving	0–500	14	14	14	14	0
			500–1000	9	9	9	9	0
			1000–1500	3	3	3	3	0
			1500–2500	2	2	2	2	0

Table C15

SU-100 KILL PROBABILITIES
(Probabilities to nearest sixteenth; i.e., 14 ≡ 14/16)

Target	Shot	Motion of target	Range, m	Concealment of target			
				Zero	Quarter	Half	Three-quarter
Dismounted Inf	Same as Blue medium tank against Red Inf, Table C11						
Mounted Inf	Same as T-34 against mounted Inf, Table C14						
Blue medium and heavy tanks	1	Stationary	0–500	14	11	7	4
			500–1000	8	6	4	2
			1000–1500	4	3	2	1
			1500–2500	2	2	1	1
	n	Stationary	0–500	14	14	14	14
			500–1000	11	11	11	11
			1000–1500	8	8	8	8
			1500–2500	5	5	5	5
	1	Moving	0–500	12	9	6	4
			500–1000	6	5	3	2
			1000–1500	2	2	1	1
			1500–2500	1	1	1	0
	n	Moving	0–500	14	14	14	14
			500–1000	8	8	8	8
			1000–1500	2	2	2	2
			1500–2500	2	2	2	2
Blue light tanks	1	Stationary	0–500	14	11	7	4
			500–1000	9	7	5	3
			1000–1500	5	4	3	2
			1500–2500	3	2	2	1
	n	Stationary	0–500	14	14	14	14
			500–1000	12	12	12	12
			1000–1500	9	9	9	9
			1500–2500	6	6	6	6
	1	Moving	0–500	12	9	6	3
			500–1000	8	6	3	2
			1000–1500	2	2	1	1
			1500–2500	1	1	1	0
	n	Moving	0–500	14	14	14	14
			500–1000	9	9	9	9
			1000–1500	3	3	3	3
			1500–2500	3	3	3	3

Table C16

BLUE MORTAR KILL PROBABILITIES
AGAINST RED INFANTRY
(Probabilities to nearest sixteenth; i.e., 8 ≡ 8/16)

Concealment	Kill probability
Zero	8
Quarter	6
Half	5
Three-quarter	3
Full	2

Annex C2

SAMPLE MOVE CALCULATION

Consider that a Blue tank is on grid square (07,19) and the decision as to which neighboring square is to be occupied next must be made. Figure C5 lists the pertinent terrain-feature data as indicated by Figs. 8 and 9.

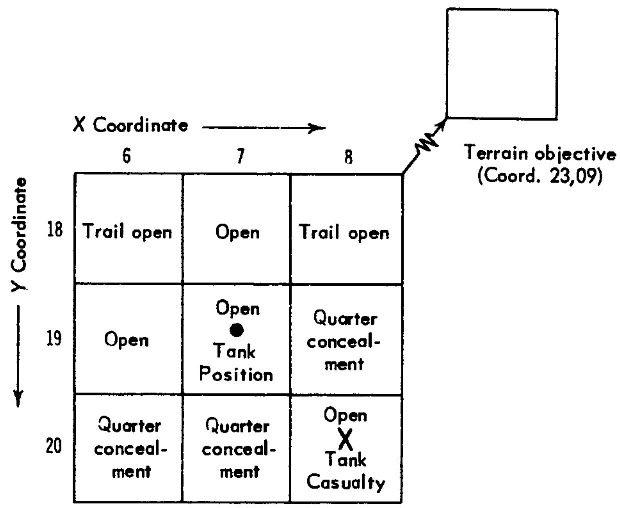


Fig. C5—Terrain Features for Sample Move Calculation

	6	7	8
18	+15	+9	+15
19	+9	+9	+11
20	+11	+11	+9

Fig. C6—Weighting Values Derived from Terrain Features Alone for Sample Move Calculation

Reference to Table C2 shows the grid squares are rated on the basis of the terrain features alone as shown in Fig. C6.

Additional weightings are calculated to account for the direction to the terrain objective located at (23,09) using the method shown on Fig. C3. The weights calculated are shown in Fig. C7.

Finally, the presence of a (friendly) tank casualty on grid square (08,20) shown on Fig. C5, requires that the grid square also be weighted by -13 (from Table C2). Combining all these weightings gives the final ratings shown in Fig. C8.

Terrain objective (Coord. 23,09)

	6	7	8
18	-4.2	+10	+18.5
19	-16	0	+16
20	-18.5	-10	+4.2

Fig. C7—Weighting Values Derived from Direction to Terrain Objective Alone for Sample Move Calculation

	6	7	8
18	+10.8	+19	+33.5
19	-7	+9	+27
20	-7.5	+1	-0.2

Fig. C8—Combined Weights for Sample Move Calculation

	6	7	8
18	10.8%	18.9%	33.4%
19	0%	9%	26.9%
20	0%	1%	0%

Fig. C9—Move Probabilities Computed for Sample Move Calculation

The move probabilities are calculated from the combined weights and are expressed as the percentage chance that the move will be made to the indicated square. Negative combined weights are given a 0 chance probability. The percentages are indicated in Fig. C9.

Appendix D

TABULATED BATTLE RESULTS

CONTENTS

CONTENTS (CONTINUED)

INTRODUCTION

This appendix gives selected results of 141 repetitions of the computer battle. Table D1 describes the general purposes served by the calculation of these battles.

Table D1

REPETITIONS OF COMPUTER BATTLE

Group	Repetitions	Type of Blue tank	Battle code	Purpose
1	4	Medium tank	A	Establish correctness of code
2	4	Medium tank	A	Test for battle intensity
3	5	Medium tank	C	Test for length of battle
4	50	Medium tank	B_1	Test for accuracy of average number of casualties from a set of battles
5	50	Light tank	B_2	Test for influence of significantly altered performance characteristics on outcome
6	7	Heavy tank	B_2	Same
7	7	Heavy tank	B_3	Same
8	14	Heavy tank	B_4	Same
	141			

Table D2

DIFFERENCES AMONG BATTLE CODES

Battle code[a]	Comparison
B_1	Type A; plus (a) delay for turret switching, (b) lifting of mortar barrage, and (c) change in terrain objectives to mathematical type
B_2	Type B_1, plus orders for computer to type out number of tank when it runs out of ammunition
C	Type B_1, without delay in firing till second half of battle
B_3	Type B_2, with time limit on battle extended from 30 to 34 1/3 min
B_4	Type B_2, with heavy tanks moving at same speed as mediums until the shooting starts, after which they revert to performance characteristics of heavy tanks

[a]The type B battle code is the one described in detail in App C.

Table D2 lists the differences among the various battle codes used.

The results of the eight battles computed with the type A battle code will not be discussed. This code was superseded by the later types for most of the computations. These first eight battles were required mainly to (a) check out

the bulk of the code, (b) establish that the computations gave the same results when repeated starting with the same random number, and (c) that the computations were within the time limits established earlier.

The third group of battles (five repetitions) demonstrated that, without the limitation on firing during (approximately) the first half of the battle, the calculations took about 1 hr for each battle. This resulted from the low kill probabilities causing a large number of rounds to be fired at each target, multiplying greatly the quantity of calculations required for each kill.

DETAILS OF A SINGLE MEDIUM TANK BATTLE

Battle 10 of the fourth group of calculations (Table D1) was typed out by the computer in the maximum available detail using the type B battle code (see section "Long Form" in App C). Annex D1 gives the significant part of the record for this battle as it was printed out by the computer.

Figures D1 to D7 show the progress of this battle at 300-sec intervals.

Movement

Tank b09 moves quite erratically; whereas b02 usually moves quite directly toward the enemy (Fig. D8). Clearly the degree to which the path of one of these units deviates from a straight line leading to the objective is governed by how strongly local terrain features are allowed to influence the tank movements relative to the "strength" of the influence of the terrain objective. The particular relative values used for these calculations (see Annex C2) provided, in some cases, a strong dependence on the local terrain features. Other values may be more representative. The point is that the erratic movement may be reduced or removed by merely adjusting the table of ratings.

Firing Activities

Table D3 summarizes the major firing activities that took place during the same medium tank battle.

Influence of Communication System

Table D3 indicates one of the outstanding characteristics of these calculations. Thus, in every case but one, two or more opposing tanks were delivering fire against each casualty, immediately preceding the kill. This results from the speed with which one tank's knowledge of the position of an enemy tank was shared with other friendly tanks. In fact the detailed print-out of this battle in Annex D1 shows not a single case where a tank, once brought under fire by the enemy, was ever able to return that fire. In other words, the number of shooters increased so rapidly that even when the kill probabilities were small the volume of fire was always sufficient to cause a kill before the target could reply.

Clearly the character of the results might be radically altered if the communication system were not assumed to function so rapidly.

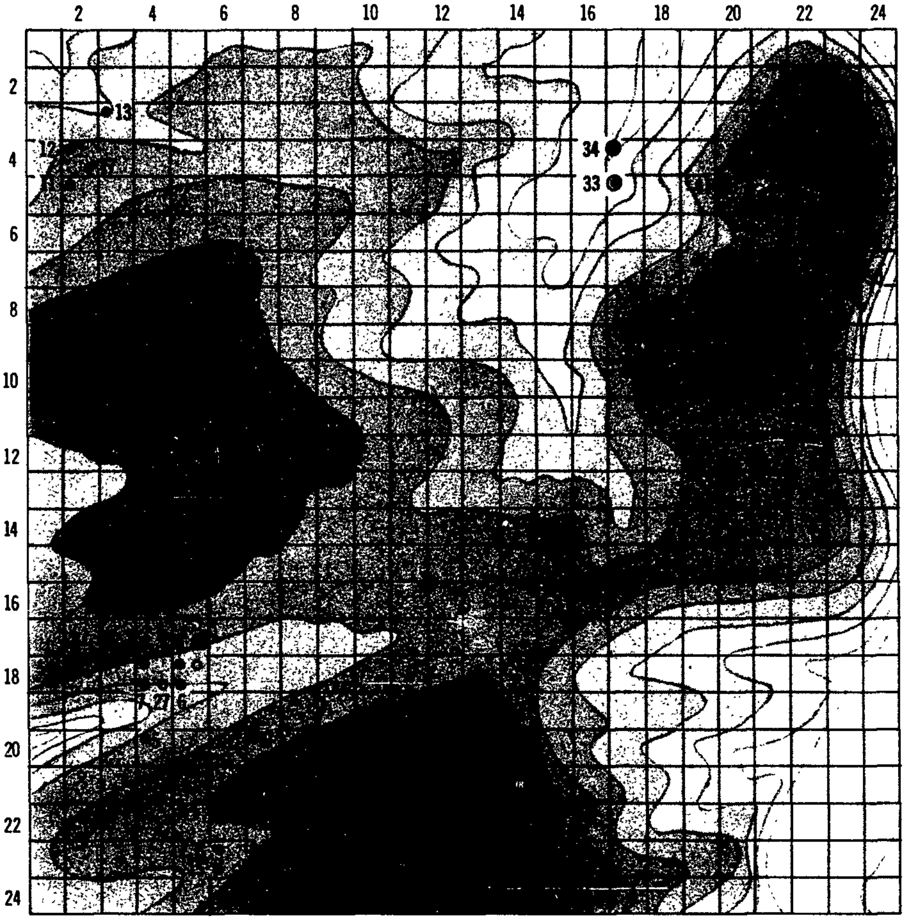


Fig. D1—Initial Position (000 Sec) of Combat Units (All Battles)

Numbers indicate code number of combat unit

● Blue tank ○ Blue infantry squad ◉ Red tank (T-34)

⊕ Red SP gun (SU-100) ◎ Red infantry squad

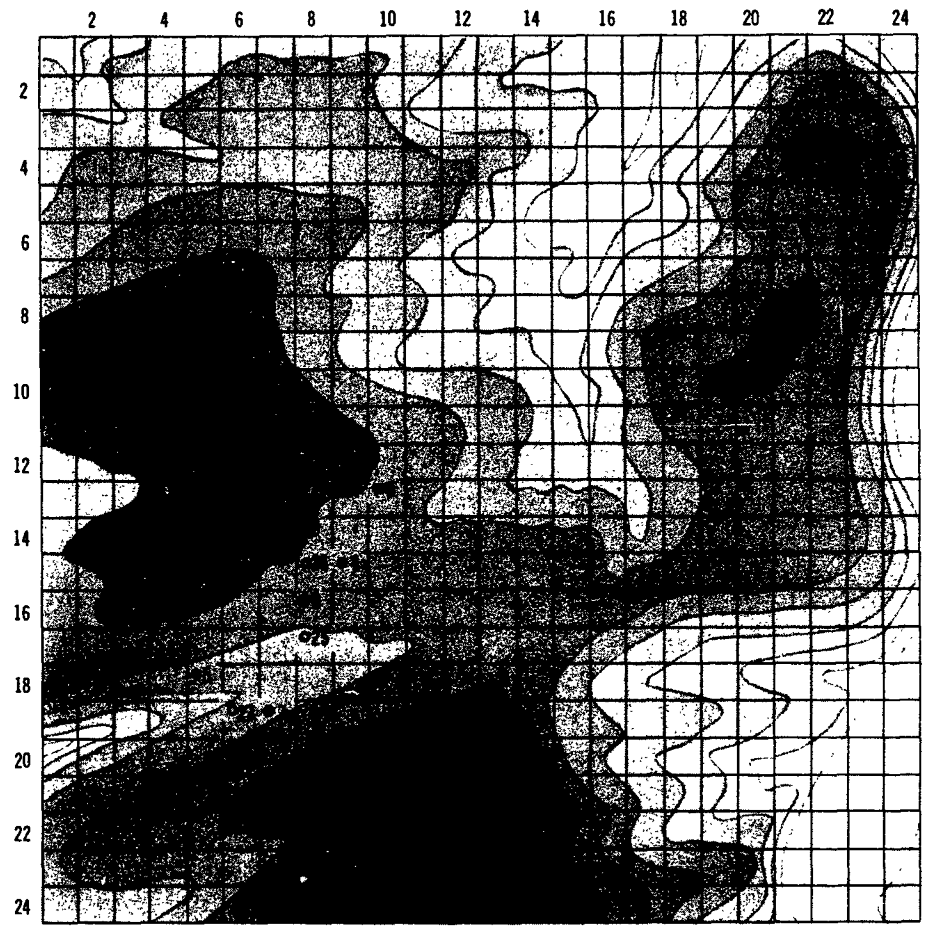


Fig. D2—Position of Blue Assault Group (300 Sec Battlefield Time)

Battle no. 10; group 4; Blue medium tanks

● Blue assaulting tanks ○ Blue assaulting infantry

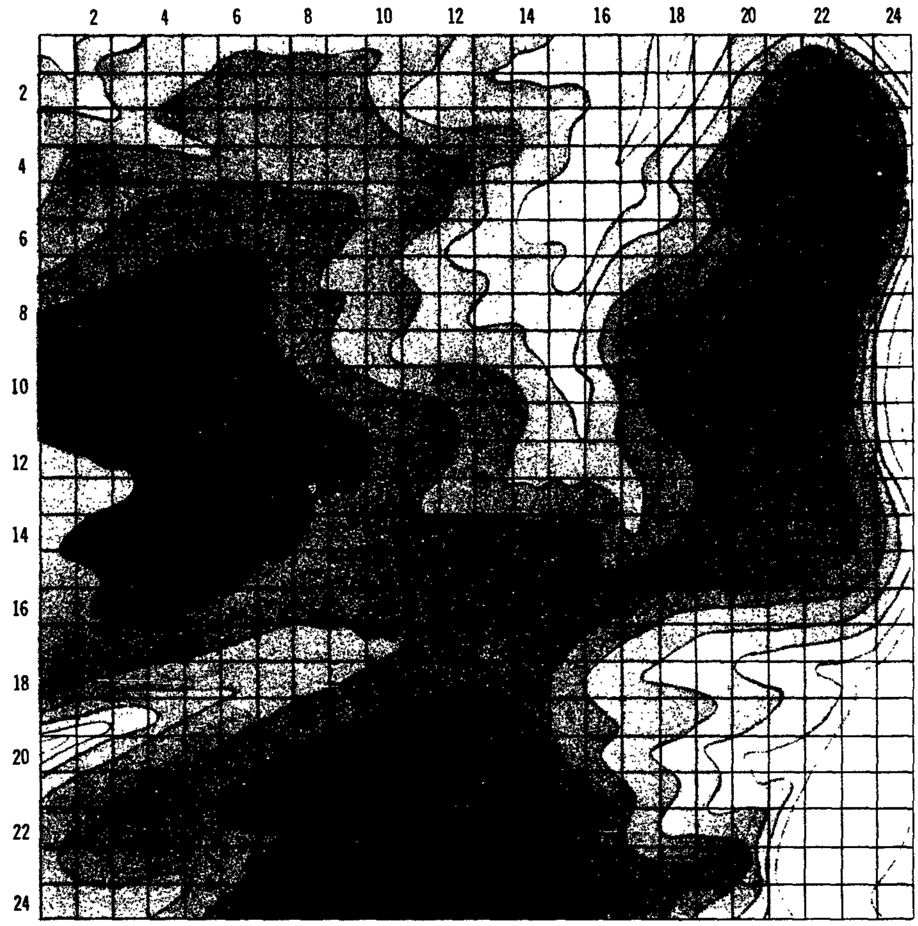


Fig. D3—Position of Blue Assault Group (600 Sec Battlefield Time)

Battle no. 10; group 4; Blue medium tanks

• Blue assaulting tanks ○ Blue assaulting infantry

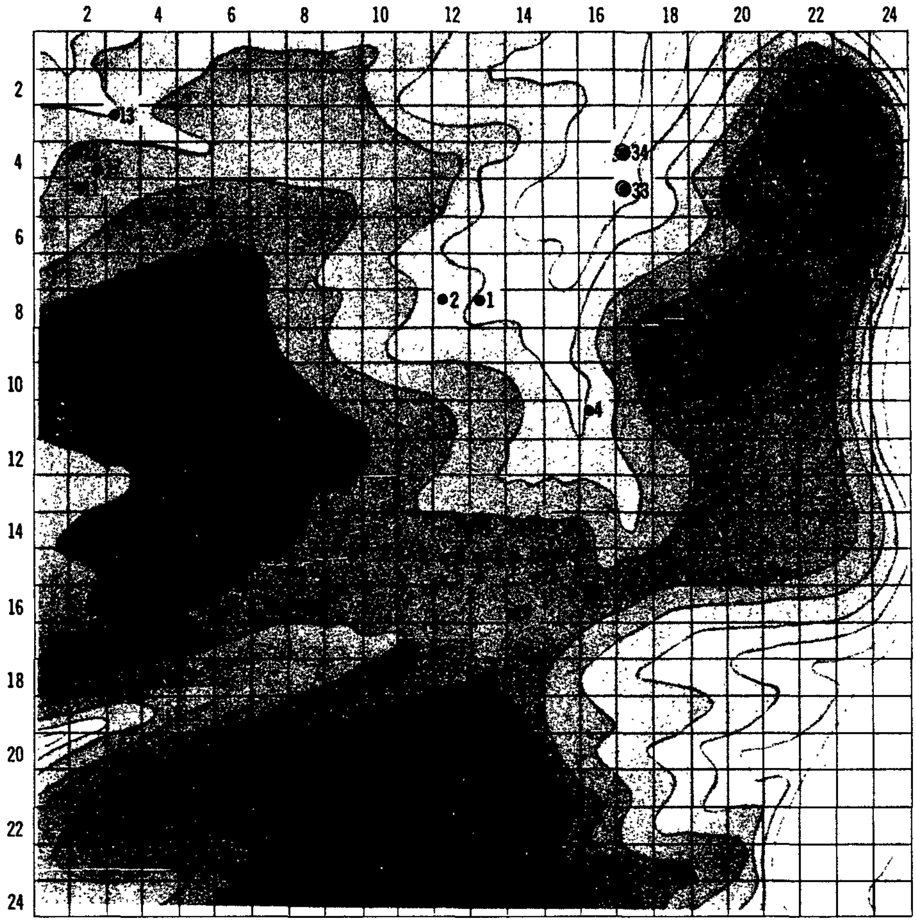


Fig. D4—Position of All Combat Units Just before Firing Starts (900 Sec Battlefield Time)

Battle no. 10; group 4; Blue medium tanks

● Blue tanks ○ Blue infantry squad

◉ Red tank (T-34) ⊕ Red SP gun (SU-100) ◎ Red infantry squad

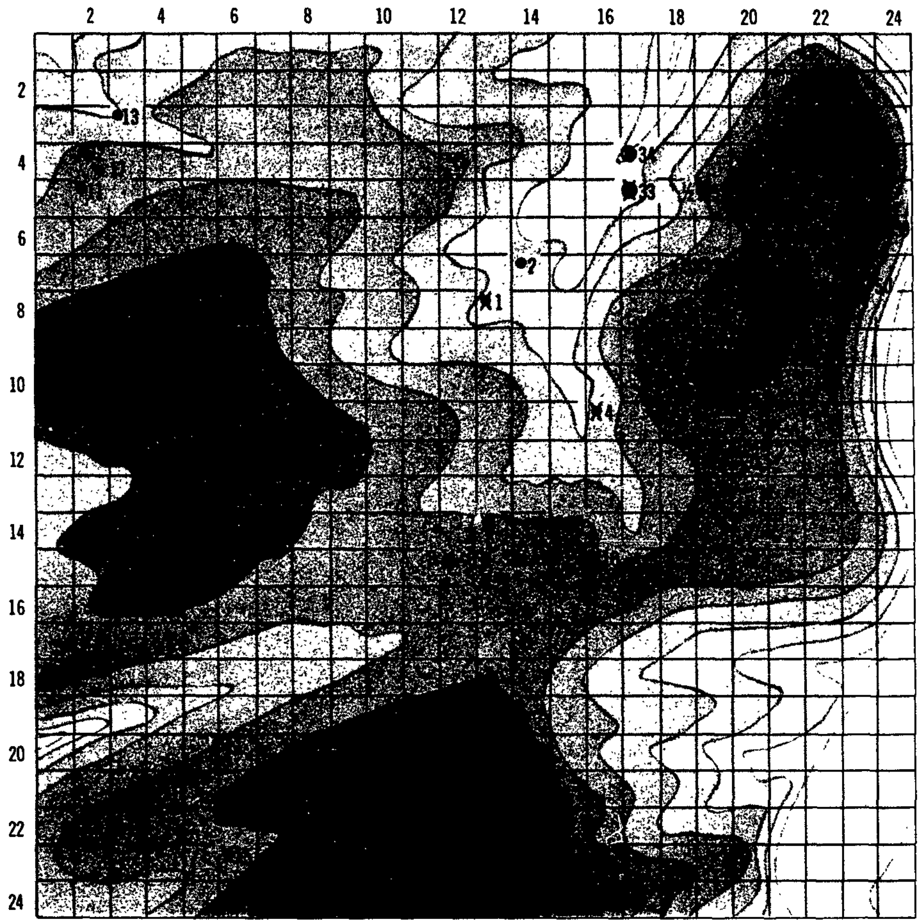


Fig. D5—Position of All Combat Units Including Casualties Occurring since Start of Firing (1200 Sec Battlefield Time)

Battle no. 10; group 4; Blue medium tanks

● Blue tank ○ Blue infantry squad X Tank casualty nX Infantry squad reduced effectiveness
◉ Red tank (T-34) ⊕ Red SP gun (SU-100) ◎ Red infantry squad

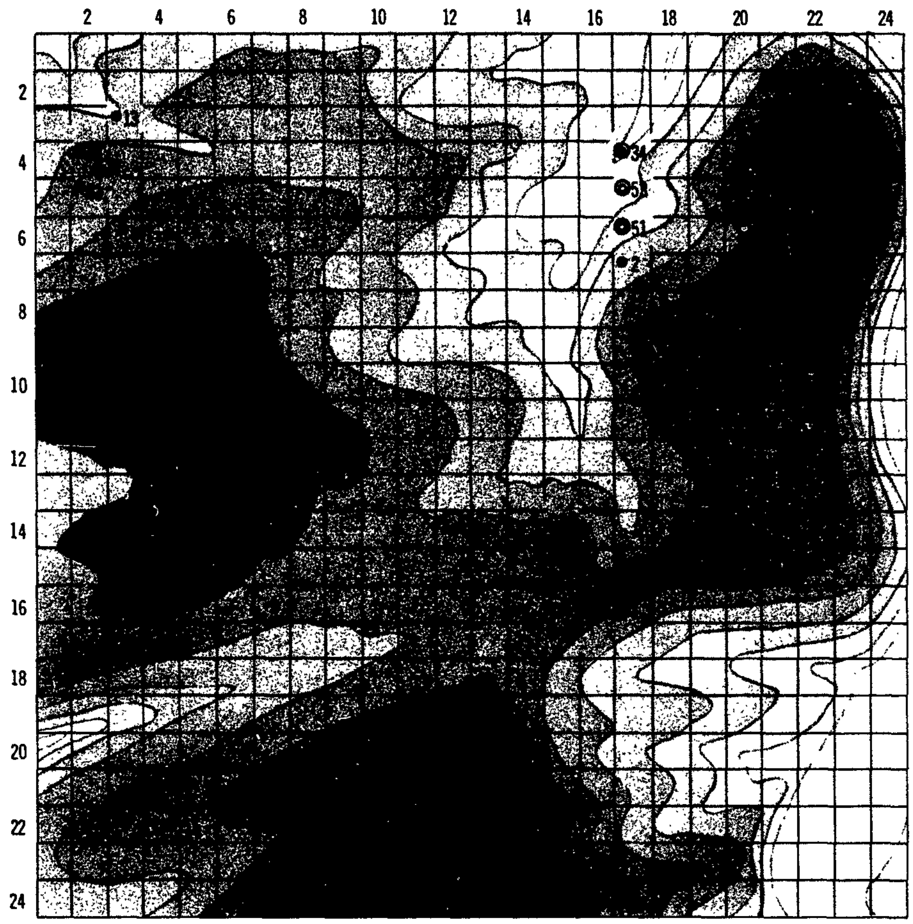


Fig. D6—Position of All Combat Units Including Units Which Became Casualties during Previous 300-Sec Interval (1500 Sec Battlefield Time)

Battle no. 10; group 4; Blue medium tanks

• Blue tank ○ Blue infantry squad X Tank casualty

◉ Red tank (T-34) ⊕ Red SP gun (SU-100) ◎ Red infantry squad

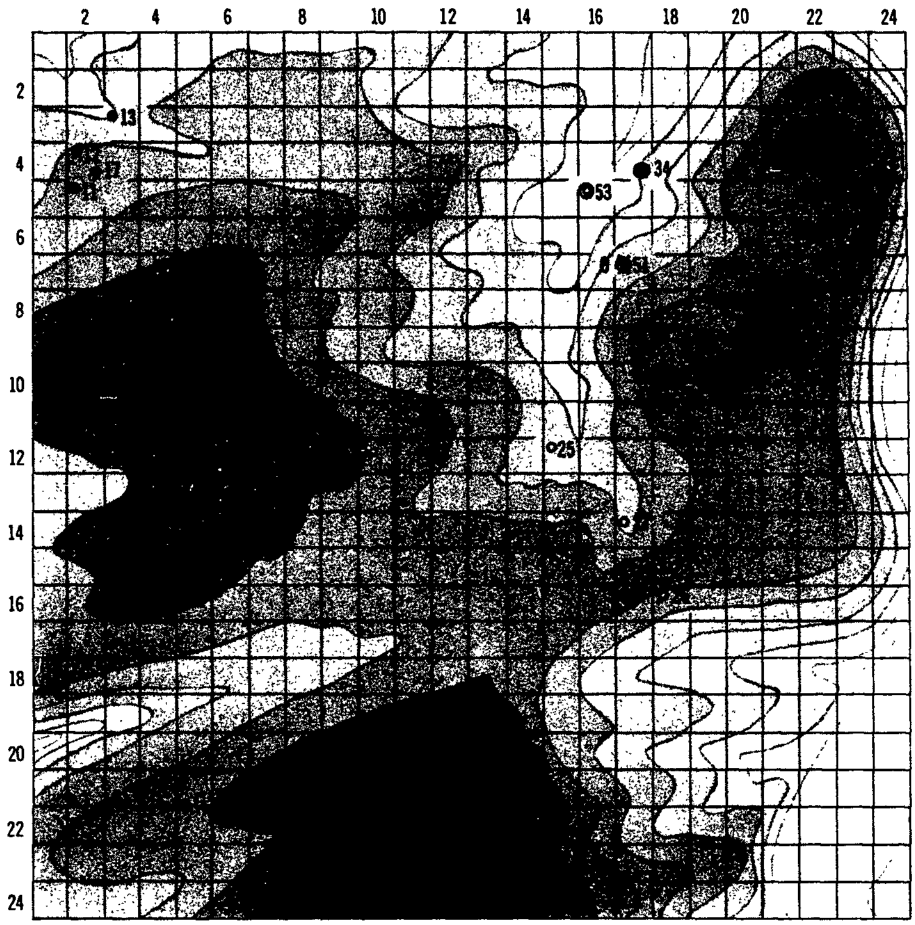


Fig. D7—Position of All Combat Units at End of Battle Calculations Including Units Which Became Casualties during Previous 300-Sec Interval (1800 Sec Battlefield Time)

Battle no. 10; group 4; Blue medium tanks

● Blue tank ○ Blue infantry squad X Tank casualty nX Infantry squad reduced effectiveness
◉ Red tank (T-34) ⊕ Red SP gun (SU-100) ◍ Red infantry squad

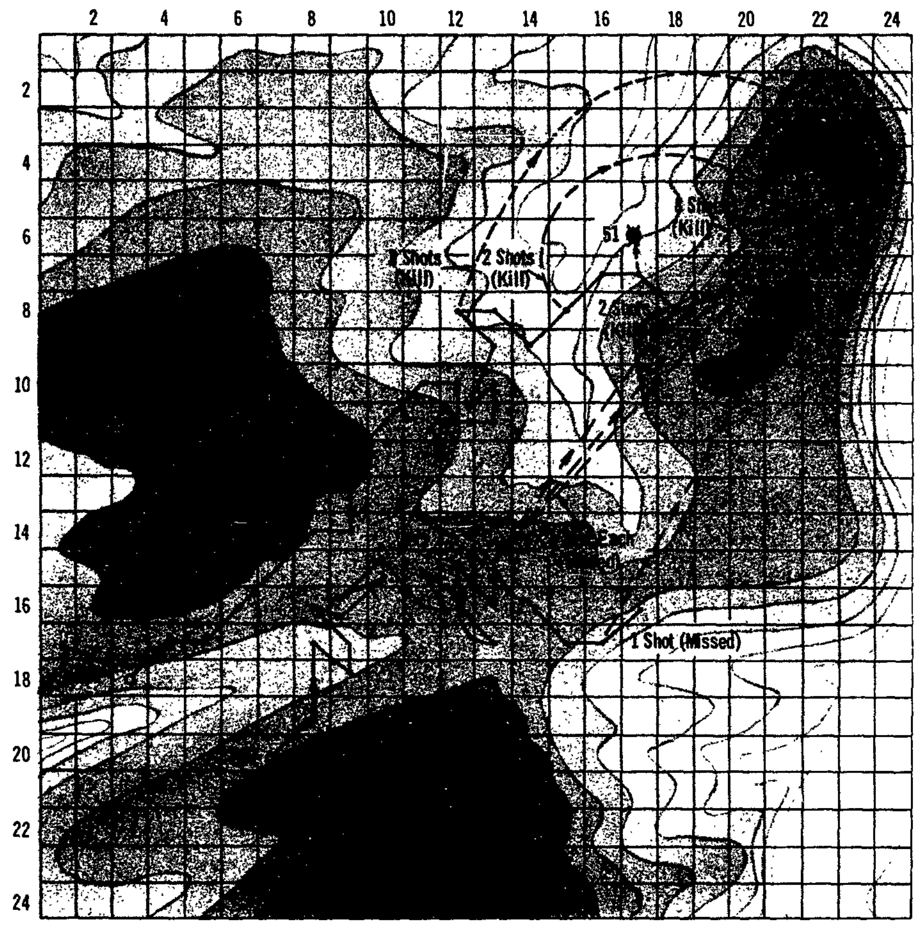


Fig. D8—Firing and Moving Activities of Two Blue Medium Tanks

Battle no. 10; group 4; test battles

A graphic representation of the complete moving and firing history of two selected Blue combat units in the same battle

Moving sequence   Firing

Table D3

MAJOR FIRING ACTIVITIES
BATTLE NUMBER 10: BLUE MEDIUM TANKS

Group	Target tank	Firing tank	Total rounds received	Total rounds fired
Blue assault tanks	1	45, 46[a]	2	0
	2		0	7
	3	35[a]	2	2
	4	35, 41, 33[a]	3	2
	5	37,[a] 34, 36, 42	9	1
	6	44[a]	5	4
	7	41,[a] 43	4	4
	8	42, 40, 44[a]	3	0
	9		0	4
	10	43,[a] 44, 34, 41	5	3
Blue over-watching tanks	11		0	3
	12		0	4
	13		0	4
	14	38, 46[a]	3	1
	15	41, 34, 43, 44	9	4
	16	39,[a] 43, 47, 39	4	2
	17		0	2
Red T-34's	33	6, 13, 7, 12, 17[a]	12	1
	34		0	6
	35	15,[a] 3	3	3
	36	11[a]	2	2
	37	2,[a] 9	4	3
	38	2[a]	2	2
	39	2,[a] 9	3	2
	40	15, 4, 16,[a] 10, 3, 5, 9, 14	10	1
	41		0	8
	42	10, 6, 7,[a] 13, 12, 11, 9	10	2
Red SU-100	43		0	6
	44		0	10
	45		0	1
	46		0	1
	47		0	1

[a]Indicates killer.

RESULTS OF 50 BLUE MEDIUM TANK BATTLES

Annex D2 gives the short-form results of the group 4 calculations, involving 50 repetitions of the battle computations. Each battle differs from the others only in the way chance influenced the Monte Carlo calculations.

Table D4 lists the total Red and Blue tank casualties in each of the battles. On the average, Blue lost 10.4 tanks and Red lost 7.1 tanks. The infantry casualties were at all times slight. The average effectiveness ratio for the Blue medium tanks corresponding to the average casualties is 60 percent; i.e., each Blue medium tank in these battles caused on the average only 60 percent as many casualties as did each Red armored vehicle.*

*The average effectiveness ratio computed from the average casualties as above is not necessarily identical to the average of the effectiveness ratios for each battle. This is because the latter is independent of the absolute number of casualties. The average of the Blue effectiveness ratios in those 50 battles is, however, almost exactly the same; 61 percent.

Table D5 gives a detailed breakdown of the casualties occurring in the various battles. It will be noted that the Red overwatching tanks (SU-100) imposed a very unfavorable exchange rate on the Blues, losing only 11 out of a possible 250, while accounting for 242 Blue casualties.

Table D4

TANK LOSSES IN 50 MEDIUM TANK BATTLES

Battle no.	Blue losses	Red losses	Battle no.	Blue losses	Red losses	Battle no.	Blue losses	Red losses
1	11	10	18	9	10	35	14	7
2	12	9	19	9	7	36	9	5
3	6	4	20	9	5	37	14	4
4	8	10	21	12	8	38	11	10
5	10	11	22	12	7	39	13	6
6	10	5	23	10	9	40	17	5
7	12	5	24	11	9	41	8	11
8	15	12	25	11	9	42	9	9
9	10	10	26	14	8	43	6	3
10	11	8	27	14	9	44	11	10
11	7	8	28	11	8	45	8	10
12	8	4	29	12	5	46	12	10
13	11	2	30	9	4	47	8	1
14	7	4	31	9	5	48	7	1
15	10	5	32	9	6	49	10	10
16	10	6	33	11	7	50	9	5
17	12	7	34	13	11			

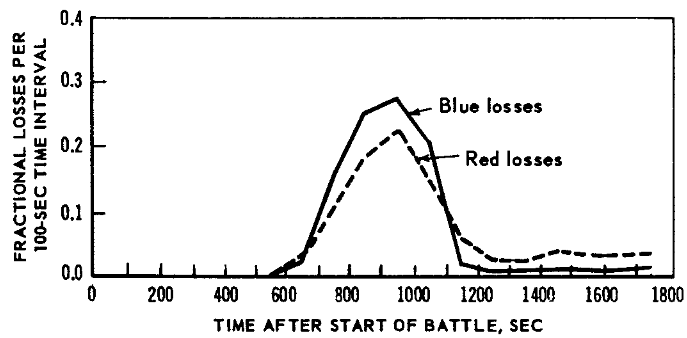


Fig. D9—Distribution of Red and Blue Tank Losses as a Function of Time, Expressed as a Fraction of Total Losses in 50 Medium Tank Battles

Fig. D9 shows the rate at which tank casualties occurred at different times during the battles. Note that roughly half the casualties occurred before the 15-min time limit, which indicates that the medium tanks had reached their first terrain objective before the overwatching tanks had opened fire.

Table D5

DISTRIBUTION OF INDIVIDUAL TANK CASUALTIES IN 50 BLUE MEDIUM TANK BATTLES[a]

			Red tanks															Totals
			T-34's										SU-100's					
			33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	
Blue medium tanks	Assaulting tanks	1	1 / 3	2 / 2	1 / 1	0 / 3	0 / 0	6 / 0	2 / 1	0 / 3	0 / 1	1 / 2	0 / 3	0 / 7	0 / 1	0 / 2	0 / 1	13 / 30
		2	2 / 4	1 / 2	1 / 1	2 / 1	2 / 0	6 / 0	4 / 1	4 / 3	3 / 2	3 / 3	0 / 7	0 / 1	1 / 0	0 / 0	0 / 1	29 / 26
		3	3 / 2	5 / 5	3 / 3	4 / 4	3 / 2	4 / 0	1 / 1	3 / 1	0 / 3	0 / 0	0 / 5	0 / 4	1 / 1	0 / 3	0 / 1	27 / 35
		4	3 / 7	2 / 0	4 / 2	1 / 4	2 / 3	3 / 2	5 / 0	3 / 0	1 / 1	1 / 0	0 / 3	0 / 5	0 / 0	0 / 3	0 / 0	25 / 30
		5	0 / 3	1 / 3	2 / 0	0 / 1	2 / 5	0 / 1	2 / 1	2 / 4	3 / 1	2 / 1	0 / 1	0 / 11	0 / 1	0 / 1	0 / 1	14 / 35
		6	3 / 3	2 / 0	4 / 3	5 / 4	0 / 2	3 / 5	0 / 0	1 / 3	1 / 1	1 / 2	0 / 4	0 / 4	0 / 2	0 / 0	0 / 1	20 / 34
		7	2 / 1	2 / 1	4 / 2	3 / 2	4 / 2	2 / 0	8 / 0	2 / 3	3 / 1	2 / 3	0 / 3	0 / 3	0 / 1	0 / 1	0 / 2	32 / 25
		8	0 / 1	0 / 0	4 / 1	2 / 1	4 / 0	1 / 1	3 / 0	1 / 3	3 / 0	1 / 2	0 / 6	0 / 8	0 / 0	0 / 0	0 / 0	19 / 23
		9	0 / 3	1 / 1	3 / 3	3 / 3	2 / 0	3 / 0	1 / 0	0 / 0	3 / 5	2 / 4	0 / 3	0 / 10	0 / 0	0 / 0	0 / 0	18 / 32
		10	3 / 3	4 / 5	2 / 1	4 / 1	2 / 1	2 / 0	3 / 1	1 / 5	4 / 1	1 / 4	1 / 6	0 / 6	0 / 0	0 / 0	0 / 0	27 / 34
	Overwatching tanks	11	2 / 0	0 / 1	1 / 1	2 / 0	4 / 0	0 / 4	0 / 8	2 / 0	5 / 1	1 / 0	2 / 3	0 / 0	0 / 3	0 / 6	0 / 3	19 / 30
		12	0 / 0	3 / 1	2 / 0	1 / 0	4 / 0	0 / 3	0 / 5	2 / 0	3 / 0	3 / 0	0 / 2	0 / 0	0 / 8	0 / 4	0 / 7	18 / 30
		13	1 / 3	2 / 0	1 / 2	4 / 0	3 / 0	0 / 8	0 / 5	1 / 0	1 / 0	8 / 0	1 / 2	0 / 0	1 / 2	0 / 7	0 / 4	23 / 33
		14	1 / 2	2 / 2	2 / 0	2 / 0	1 / 0	0 / 6	0 / 3	3 / 0	1 / 2	4 / 0	0 / 2	0 / 0	0 / 2	1 / 6	0 / 4	17 / 29
		15	2 / 1	2 / 5	4 / 1	3 / 2	2 / 3	0 / 0	0 / 0	2 / 2	2 / 3	3 / 2	0 / 1	0 / 10	1 / 0	1 / 0	0 / 0	22 / 30
		16	3 / 0	1 / 1	0 / 0	1 / 0	2 / 0	0 / 4	0 / 5	3 / 0	1 / 0	1 / 0	0 / 1	0 / 0	1 / 6	0 / 6	0 / 8	13 / 31
		17	6 / 0	3 / 0	2 / 1	1 / 1	1 / 0	0 / 5	0 / 4	1 / 0	1 / 0	1 / 0	0 / 1	0 / 0	0 / 9	0 / 6	0 / 6	16 / 33
Totals			32 / 36	33 / 29	40 / 22	38 / 27	38 / 18	30 / 39	29 / 35	31 / 27	35 / 22	35 / 23	4 / 53	0 / 69	5 / 36	2 / 45	0 / 39	352 / 520

[a]Key: 4 [38: 3 / 2] Blue tank 4 killed Red tank 38, 3 times; Red tank 38 killed Blue tank 4, 2 times.

Infantry Activities

The activities of the infantry units during the 50 battles did not significantly affect the principal results, which were the number of tank casualties. Table D6 summarizes the casualties occurring during the battles that did involve the infantry units. There was at least one example of every possible interaction among tank and infantry units, but nowhere was a Red tank killed by a Blue infantry unit.

Statistical Reliability

A common measure of the uncertainty that must be associated with an average m computed from a limited series of tests is given by

$$c = 3s/\sqrt{n},$$

where s is the standard deviation about the mean (average) of the distribution and n is the number of repetitions. For normal distributions the odds are then about 300 to 1 that the true average lies somewhere in the interval $m-c$ to $m+c$ (plus or minus three standard deviations from the mean).

For the case of the Red tank losses while defending against Blue medium tanks, the value of s is 2.74 tanks per battle. Hence $c = 1.16$, and the odds are about 300 to 1 that the "correct" average Red tank loss lies in the interval 7.1 - 1.2 = 5.9 to 7.1 + 1.2 = 8.3 tanks per battle.

Similarly the distribution of Blue medium tank losses yields a value of s = 2.33 tanks per battle. Hence $c = 1.0$ tank per battle, and the odds are about 300 to 1 that the "correct" average Blue tank losses lies in the interval 10.4 - 1.0 = 9.4 to 10.4 + 1.0 = 11.4 tanks per battle. Since Fig. 16 indicates no strong dependence of the number of Blue tank casualties on Red tank casualties these probabilities may be assumed to be substantially independent.* It follows that the

*The assumption that the two distributions are statistically independent is only an approximation. Actually the coefficient of correlation (see, for example, Johnson[6]) for the medium tank battles is

$$r_{xy} = [(\bar{x}\bar{y}) - (\bar{x})(\bar{y})]/s_x s_y ,$$
$$= 0.278 ,$$

where $(\bar{x}\bar{y})$ = average of the products of the Red and Blue losses in each battle

$\bar{x}(\bar{y})$ = average Red (Blue) loss

$S_x(S_y)$ = standard deviation in the Red (Blue) losses.

This result is significant at the 0.05 level ($r_{0.05} = 0.269$). However, a positive correlation coefficient increases the significance of the observed difference in the mean losses of the Red and Blue forces compared to the case where the Red and Blue losses are independent, because

$$S_{\bar{x}-\bar{y}} = \sqrt{(S_x^2 + S_y^2 - 2r_{xy}S_xS_y)/N} ,$$

where $S_{\bar{x}-\bar{y}}$ = standard deviation of the difference in the mean between two samples drawn from the same population

S_x = standard deviation of the Red tank losses

S_y = standard deviation of the Blue tank losses

N = number of test battles.

Clearly as r becomes larger, the standard deviation in the difference of the means becomes smaller, so that the observed difference between the means includes an increasing number of standard deviations. In this case $S_{\bar{x}-\bar{y}} = 0.44$ so that the Red and Blue mean losses are observed to be separated by 3.34/0.44 = 7.6 standard deviations. That this should happen by chance alone is many times more unlikely even than the approximate calculation given in the text above of 1 chance in 360,000.

Thus if the null hypothesis is taken to be that the true difference between the mean Red and Blue losses is 0, then the hypothesis may be rejected. If the selected null hypothesis had asserted any superiority of Blue over Red, it would have been rejected with even more confidence.

Table D6

ACTIVITIES[a] OF INFANTRY UNITS IN 50 BLUE MEDIUM TANK BATTLES

Battle no.	Red Infantry casualties from:			Blue Infantry casualties from:		Tank casualties from:	
	Mortars	Tanks	Infantry	Tanks	Infantry	Red Infantry	Blue Infantry
1	0						
2	4 (6)						
3	4 (5)						
4	3						
5	2			1 (2)			
6	3 (4)						
7	3			1 (2)	1 (2)		
8	3						
9	3 (5)						
10	1	1 (6)					
11	2	1 (4)					
12	5						
13	1						
14	1						
15	2						
16	1						
17	1						
18	2			1 (4)			
19	1						
20	2						
21	0						
22	2						
23	2						
24	2		1 (1)				
25	4 (6)						
26	2			1 (2)	1 (2)		
27	1						
28	2 (3)						
29	3			1 (4)			
30	4						
31	1						
32	5						
33	2						
34	3						
35	0					1 (1)	
36	1			1 (4)			
37	3						
38	0						
39	0						
40	0						
41	2 (3)						
42	2						
43	1						
44	0						
45	2				1 (6)		
46	3						
47	1						
48	2						
49	3				1 (1)		
50	2			1 (4)			

[a]Table entries in parentheses are number of hits on indicated number of units.

probability that the correct mean Blue losses should be as low, or lower, than 9.4 tanks per battle is 1 in 600; and the probability that the correct mean Red losses should be as high, or higher, than 8.3 tanks per battle is 1 in 600; and the probability that the two circumstances be simultaneously true is the product of these two probabilities or 1 in 360,000.

These calculations show that the odds overwhelmingly indicate that the Red forces would, on the average, suffer fewer casualties than the Blue forces, no matter how many additional battles were computed. Therefore the sample size of 50 battles may be presumed to be sufficiently large to identify the winning side correctly.

RESULTS OF 50 BLUE LIGHT TANK BATTLES

All performance characteristics referring to the type of Blue tank were altered so that Blue might be equipped with a hypothetical light tank. The killing power of its gun and the vulnerability of its armor were derived from tentative

Table D7

TANK LOSSES IN 50 LIGHT TANK BATTLES[a]

Battle no.	Blue losses	Red losses	Battle no.	Blue losses	Red losses	Battle no.	Blue losses	Red losses
1	6	9	18	5	9	35	8	10
2	9	9	19	9	9	36	8	8
3	6	9	20	2	8	37	5	9
4	4	10	21	9	10	38	6	7
5	7	10	22	4	8	39	3	8
6	7	7	23	5	7	40	4	7
7	6	4	24	9	7	41	6	7
8	9	10	25	6	9	42	5	9
9	5	9	26	9	10	43	7	7
10	4	3	27	11	9	44	6	7
11	8	7	28	6	10	45	3	6
12	6	10	29	3	4	46	6	8
13	11	9	30	10	8	47	9	9
14	6	8	31	6	10	48	6	10
15	5	9	32	4	10	49	7	8
16	5	8	33	8	8	50	6	10
17	7	11	34	11	10			

[a]All Blue medium tanks replaced with light tanks.

calculations for the T41 tank and are discussed in App C. Entirely hypothetical were the assumed doubled speed and rate of fire (both referred to the Blue medium tank). Except for performance data no other changes were made in the code.

Distribution of Tank Casualties

Table D7 gives the tank losses of both sides for these battles. On the average Red lost more tanks (8.4 tanks per battle) than Blue (6.5 tanks per battle). On this basis, Blue may be said to have "won" the battle when equipped with the

hypothetical light tanks in contrast to "losing" the battle when equipped with mediums. The average exchange rate for these battles was 1.1 in favor of Blue, almost twice as great as the value of 0.6 previously computed for the Blue exchange rate in the medium tank battles.

Statistical Reliability

The chance that the observed "superiority" of Blue over Red (average excess Red loss of 8.4 - 6.5 = 1.9 tanks per battle more than the Blue losses) does not represent the true state of affairs and was due to chance alone must be determined. The calculation is the same as for the medium tank battles.

Figure D10 gives the results of the series of battles in the form of a scatter diagram. No strong correlation is indicated.

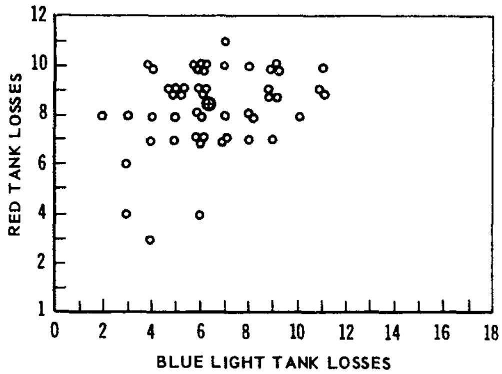


Fig. D10—Scatter Diagram Indicating Degree of Independence of Blue and Red Tank Losses

Each point corresponds to outcome of one battle of the 50 battles computed. Data from Table D7.

⊕ = average losses (8.4 Red; 6.5 Blue)

Using the same equations for the same purposes as in the case of the medium tanks, three standard deviations in the mean Red casualties are subtracted from the observed mean number of Red tank casualties. This gives

$$8.4 - 3(1.66/\sqrt{50}) = 7.7 \text{ tank casualties per battle}$$

The quantity in parenthesis is the standard deviation in the mean, computed by dividing the standard deviation of distribution of Red casualties by the square root of the number of battle repetitions. The chance that the true mean would be less than the observed mean (8.4 tanks per battle) by as much or more than three standard deviations in the mean is about 1 in 600. Similarly the chance that the true mean number of Blue light tank casualties should be as much as, or more than, three standard deviations in the mean greater than the observed number of Blue light tank casualties is 1 in 600; this puts an upper confidence limit on the mean number of Blue casualties of

$$6.5 + 3(2.38/\sqrt{50}) = 7.6 \text{ casualties per battle}$$

Table D8

DISTRIBUTION OF RED AND BLUE TANK LOSSES IN 50 BLUE LIGHT TANK BATTLES[a]

		Red tanks															Totals
		T-34's										SU-100's					
		33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	
Blue light tanks — Assaulting tanks	1	5 1	1 2	0 0	1 1	1 1	0 1	0 0	1 2	0 1	1 2	0 ,5	0 1	0 4	0 3	0 4	10 28
	2	1 3	3 2	2 0	2 2	2 2	0 1	3 0	0 1	2 2	4 1	0 5	0 3	0 2	0 5	0 1	19 30
	3	4 1	4 3	5 1	0 3	1 0	2 1	2 1	1 0	2 0	2 1	0 2	0 2	0 5	0 6	1 5	24 31
	4	5 1	2 0	2 0	5 0	2 1	3 2	2 1	2 0	1 1	3 0	0 5	0 2	0 2	0 3	0 7	27 25
	5	2 0	2 3	2 3	1 1	4 1	1 0	1 0	5 0	1 5	3 1	0 3	0 5	0 1	0 3	1 4	23 30
	6	3 2	3 1	5 2	0 1	1 1	10 2	0 1	1 0	3 0	3 0	0 2	0 1	0 6	0 5	1 4	30 28
	7	1 1	4 0	4 0	4 1	4 0	1 1	4 6	5 1	3 1	0 1	0 6	0 2	0 6	0 2	0 2	30 30
	8	4 2	3 0	2 1	2 1	4 0	2 0	3 3	7 1	0 3	4 0	0 5	0 3	0 5	0 5	1 5	32 34
	9	2 0	3 2	3 0	4 0	3 0	3 0	5 1	1 1	4 3	2 0	0 3	0 2	0 4	0 3	1 5	31 24
	10	1 0	0 0	2 3	0 1	0 2	1 1	2 3	1 1	0 0	8 0	0 4	0 5	0 3	0 6	0 4	15 33
Blue light tanks — Overwatching tanks	11	4 0	2 0	3 0	4 0	2 0	0 0	1 0	4 0	3 0	5 0	0 0	0 0	0 0	0 0	0 0	28 0
	12	1 0	2 0	4 0	1 0	1 0	4 0	2 0	2 0	3 0	0 0	0 0	0 0	0 0	0 0	0 0	20 0
	13	2 0	2 0	4 0	3 0	2 0	1 0	3 0	1 0	6 0	1 0	0 0	0 0	0 0	0 0	0 0	25 0
	14	5 0	4 0	0 0	4 0	4 0	1 0	4 0	2 0	4 0	0 0	0 0	0 0	0 0	0 0	0 0	28 0
	15	0 3	1 0	2 1	3 1	2 1	0 1	1 1	0 2	1 1	0 0	0 3	0 5	0 2	0 5	0 3	10 29
	16	3 0	2 0	2 0	5 0	5 0	6 0	3 0	3 0	4 0	6 0	0 0	0 0	0 0	0 0	1 0	40 0
	17	2 0	2 0	2 0	3 0	5 0	3 0	3 0	4 0	1 0	1 0	0 0	0 0	0 0	0 0	0 0	26 0
Totals		45 14	40 13	44 11	42 12	43 9	38 10	39 17	40 9	38 17	43 6	0 43	0 31	0 40	0 46	6 44	418 322

[a]Key: 1 $\boxed{\begin{matrix}5\\1\end{matrix}}$ (column 33) Blue tank 1 killed Red tank 33, 5 times; Red tank 33 killed Blue tank 1, 1 time.

If the distributions are taken as independent,* the combined chance that both the average Red losses should be less than 7.7 tanks per battle and, simultaneously, the average Blue tank losses more than 7.6 tanks per battle, is the product of these two probabilities or (1/600) × (1/600) equals 1/360,000. Thus the odds overwhelmingly favor the hypothesis that the Blue forces would suffer less casualties than the Red forces no matter how many additional calculations of this battle were made.

Discussion of Results

Table D8 gives the performance of each individual tank in these 50 battles, both in terms of the enemy tanks they "killed" as well as the enemy tanks by which they were killed. This shows that the most striking reduction in Blue casualties has been among the overwatching tanks, only one of which (tank 15) was ever a casualty. There may have been a modest reduction in the number of casualties among the light tank assault group. Thus the average number of battles in which an assaulting Blue medium tank was killed is calculated from the data in Table D5 and found to be 30.4. The corresponding average for the assaulting light tanks is 27.5. However, the reduction in number of battles is only barely significant, being a drop of 2.5 standard deviations in the mean. The chance against this happening by chance alone is about 1 in 100. This factor is usually taken to be large enough to reject the hypothesis that the difference between 30.4 and 27.5 may be considered as due to chance alone. However, the difference is not large in any event, and, withall, a probability of 0.01 is not so small as would be desirable.

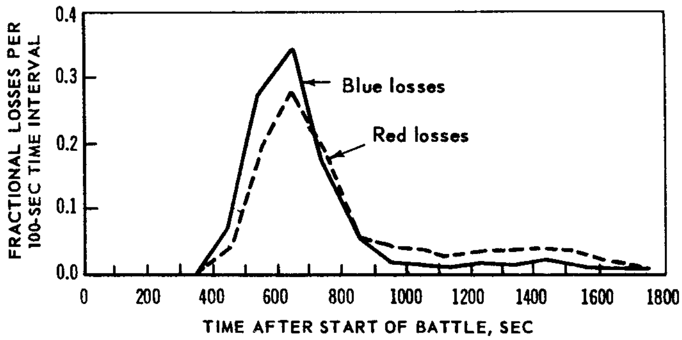


Fig. D11—Distribution of Red and Blue Tank Losses as a Function of Time, Expressed as a Fraction of Total Losses in 50 Light Tank Battles

This is a striking example of the requirement that a detailed investigation of the reason for superior performance be carried out. Figure D11 illustrates the most obvious difference between the series of medium and light tank battles.

*As in the case of the medium tanks this is only an approximation. The coefficient of correlation r is computed to be 0.327, which is significant at the 0.05 level, though not at the 0.01 ($r_{0.01}$ = 0.354). Again the effect of this positive correlation coefficient is to increase the odds computed above (360,000 to 1). In fact the mean Red and Blue losses are computed to be separated by 5.9 standard deviations, which is many times larger than is required to reject the null hypothesis that the Red and Blue mean losses were "actually" the same.

For the light tank battles the highest rate of casualties occurred between 600 and 700 sec. For the medium tank battles, the highest rate of casualties occurred between 900 and 1000 sec. This suggests a possible mechanism to account for the lack of casualties among the overwatching tanks during the 50 light tank battles. Evidently the light tanks appeared at the edge of the Red position so rapidly that they distracted the attention of the Red tanks from the more distant and stationary overwatching tanks to the extent that Red tanks concentrated their fire on the assaulting elements only. Due to the limited number of calculations permitted by the feasibility study, no detailed investigation of this unusual circumstance was possible.

Annex D3 gives the detailed (long form) moving and firing record of one of the light tank battles.

Annex D4 gives the detailed (short form) results of the 50 Blue light tank battles.

RESULTS OF 14 BLUE HEAVY TANK BATTLES

Table D9 gives the results of 14 battle calculations, where the Blue forces were assumed to be equipped with heavy tanks. Although the sample is too small to lend weight to the results, the Blue forces did impose an unfavorable exchange ratio on the Red forces, losing an average of 5.4 tanks per battle to the Red forces' loss of an average of 8.8 tanks per battle.

Table D9

TANK LOSSES IN 14 BATTLE CALCULATIONS
(Blue equipped with heavy tanks)

Battle no.	Blue losses	Red losses	Battle no.	Blue losses	Red losses
1	5	8	8	3	9
2	4	9	9	8	9
3	7	9	10	6	6
4	5	10	11	8	8
5	6	11	12	6	9
6	4	10	13	4	9
7	4	9	14	6	8

Figure D12 shows the distribution of tank casualties for both sides. Due to the limited number of battles and the observed spread of results, the statistical reliability of these results is not so high as was the case for the medium tank and light tank battles. Even so, the standard deviation in the Red losses is 1.24 tanks per battle and in the mean is 0.332 tanks per battle. Hence three standard deviations in this mean is 1.00 tank per battle and hence the odds against the true Red losses being as low as 7.8 tanks per battle are about 300 to 1. Similarly the odds against the true Blue losses being as high or higher than

$$5.4 + 3(1.40)/(\sqrt{14}) = 6.5 \text{ tanks lost per battle}$$

are also 300 to 1. Thus, if the losses may be considered as being statistically independent (as was the case for the previous 100 battles) then the odds against both of these being simultaneously true are, as before, 360,000 to 1. Hence the

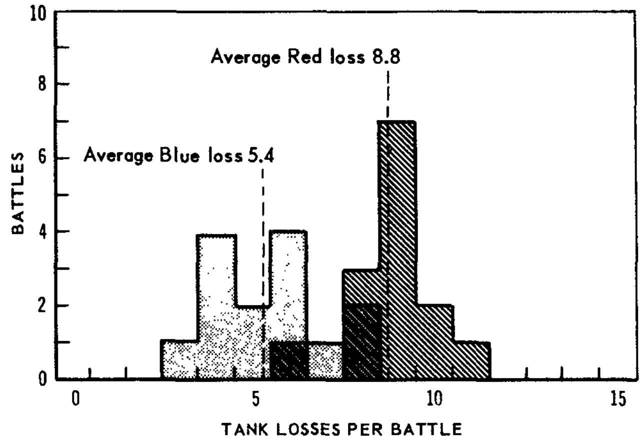


Fig. D12—Distribution of Tank Losses in 14 Blue Heavy Tank Battles

odds are overwhelming that the Blue tanks would continue to lose the lesser number of tanks no matter how many additional battles were calculated.

Note that the difference in the mean losses for these heavy tanks was 3.4 tanks per battle, which is the largest difference noted in these three sets of battles.

Annex D5 gives the (short form) results of these 14 Blue heavy tank battles.

Annex D1

LONG-FORM PRINT-OUT OF BLUE MEDIUM TANK BATTLE 10

In the short-form print-out the R No. is the random number selected as the point from which the battle begins. The short-form print-out preceding the long forms has been included to facilitate identification of critical events. For key to print-outs see "Format for Results" in App C.

SHORT-FORM SUMMARY OF RESULTS OF BATTLE 10, GROUP 4

R No. 11321055

b08	918	12,15	r44	21, 4	1
b01	923	13,08	r46	18,10	1
r53	925	20,05	b31	0, 0	8
b04	926	16,11	r33	17, 5	1
r40	930	21,04	b16	1,11	2
r36	953	20,05	b11	2, 5	2
b16	953	1,11	r39	23, 6	2
b05	955	14,14	r37	23, 4	3
r33	955	17,05	b17	2, 4	2
b14	959	5,07	r46	18,10	1
b03	966	14,15	r35	20, 7	2
r37	967	23,04	b02	12, 8	3
r35	972	20,07	b15	6,23	2
r42	1000	23,03	b07	13,14	2
b07	1000	13,14	r41	20, 5	3
b06	1013	3,15	r44	21, 4	5
b15	1062	6,23	r41	20, 5	3
b10	1098	16,15	r43	20, 7	2
r38	1298	22,06	b02	15, 8	2
r51	1503	17,06	b02	17, 7	12
r51	1517	17,06	b02	17, 7	9
r51	1531	17,06	b02	17, 7	6
r51	1558	17,06	b02	17, 7	3
r51	1601	17,06	b02	17, 7	0
r51	1617	17,07	b02	17, 7	0
r39	1680	22,06	b02	18, 8	2

b11 r8 hit

LONG-FORM PRINT-OUT OF BATTLE 10

b31	0000.00		b27	0298.95	06,19	b31	0620.03			r54	0860.73		nsf		b05	0925.53		r40	
b06	0000.01	06,17	b06	0299.64	10,13	b02	0622.85	12,11		b01	0860.75		nsf		r52	0925.57		nsf	
b04	0000.06	05,17	b01	0305.40	07,15	b03	0626.34	10,17		r49	0860.90		nsf		b31	0925.62		r53	yes
b05	0000.15	05,20	b05	0307.64	08,18	b02	0630.62	13,11		r48	0861.01		nsf		b09	0925.70		r40	
b10	0000.20	07,22	b31	0310.42		b31	0630.64			b13	0861.32		nsf		b14	0926.67		r40	
b26	0000.39	05,17	b27	0317.42	07,18	b26	0632.09	11,14		r40	0861.34		nsf		r33	0926.78		b04	yes
b27	0000.45	nc	b02	0322.46	09,14	b10	0632.98	14,16		r41	0861.34		nsf		b15	0926.95		r40	
b08	0000.45	nc	b04	0324.95	10,14	b09	0636.89	13,17		r56	0861.42		nsf		b25	0928.26		r40	
b02	0000.46	04,17	b09	0327.14	09,16	b02	0649.64	13,10		b16	0861.42		nsf		r42	0928.71		nsf	
b07	0000.60	nc	b06	0332.31	11,14	b01	0656.93	12,12		b02	0861.45		nsf		r40	0928.87		nsf	
b25	0000.70	nc	b07	0337.09	08,19	b07	0660.17	12,15		r46	0861.45		nsf		b27	0929.17		r40	
b03	0000.76	nc	b10	0338.95	12,20	b27	0663.42	nc		b09	0861.68		nsf		r54	0929.39		nsf	
b01	0000.82	03,17	b26	0340.46	09,15	b31	0665.64			b06	0861.75		nsf		r47	0929.50		nsf	
b09	0000.92	08,19	b25	0344.21	09,17	b05	0667.42	11,17		r36	0861.89		nsf		r37	0929.59		b05	
b08	0003.45	nc	b05	0345.84	08,19	b04	0668.03	14,13		r33	0863.21		nsf		b13	0930.00		r33	
b25	0005.37	06,22	b08	0348.82	11,19	b27	0669.65	12,17		b10	0867.76	15,16			r35	0930.37		nsf	
b27	0010.90	06,19	b09	0354.23	10,15	b26	0672.68	nc		b31	0868.31				b16	0930.37		r40	yes
b03	0018.43	05,19	b25	0355.98	10,16	b03	0676.70	11,16		b09	0881.03	13,15			b10	0930.57		nsf	
b07	0025.92	05,18	b05	0358.87	09,18	b27	0681.71	13,16		b26	0881.35	nc			r34	0930.73		b05	
b08	0030.09	07,24	b03	0359.60	nc	b25	0691.51	12,16		b25	0886.25	14,15			b07	0930.89		r33	
b02	0054.12	05,17	b31	0362.48		b10	0693.09	15,15		b02	0886.32	12,08			r56	0930.90		nsf	
b31	0059.43		b01	0362.76	08,14	b26	0700.37	12,14		b01	0889.34	13,08			r36	0932.65		b05	
b10	0064.64	08,22	b03	0375.31	07,19	b09	0701.04	12,16		r52	0890.51		nsf		b12	0932.89		r33	
b06	0067.09	07,17	b27	0375.59	08,19	b04	0706.59	15,13		b14	0892.96		nsf		r44	0933.10		nsf	
b26	0068.32	05,16	b02	0378.78	09,13	b02	0706.73	12,11		b15	0893.25		nsf		b26	0934.18		r35	
b25	0072.00	07,21	b07	0379.71	09,19	b07	0707.64	11,14		b04	0894.17		nsf		b11	0935.82		r36	
b09	0078.60	08,18	b04	0387.00	11,15	b27	0707.73	14,15		r45	0894.18		nsf		r50	0936.42		b14	
b05	0081.03	06,20	b09	0390.31	09,16	b01	0716.95	13,11		b27	0894.26		nsf		r38	0936.42		b14	
b01	0081.76	14,17	b06	0393.68	12,15	b04	0722.37	15,12		r35	0895.07		nsf		r51	0936.53		b14	
b03	0081.82	06,20	b26	0396.20	09,16	b05	0725.39	nc		b16	0895.07		nsf		b09	0936.79		nsf	
b07	0087.01	nc	b31	0397.15		b31	0726.93			r56	0895.14		nsf		r53	0937.21		nsf	
b27	0091.53	06,18	b04	0398.68	12,15	b04	0733.92	16,13		b25	0897.01		nsf		r41	0938.25		nsf	
b04	0092.07	06,17	b10	0400.79	nc	b01	0734.46	13,10		r42	0897.46		nsf		r39	0938.67		b16	
b07	0096.42	05,19	b02	0406.37	09,12	b03	0741.64	11,15		r40	0897.62		nsf		r43	0938.92		b16	
b02	0098.73	06,16	b08	0409.34	11,18	b31	0746.14			b03	0898.39	14,15			b02	0939.07		r37	
b06	0099.76	07,16	b25	0416.09	10,17	b05	0753.09	12,16		b10	0898.84		nsf		b14	0939.20		nsf	
b10	0114.68	08,21	b10	0424.68	13,19	b09	0756.56	12,15		r44	0899.32		nsf		b17	0939.50		r33	
b01	0117.54	04,16	b01	0424.82	08,13	b04	0761.56	16,12		r53	0901.29		nsf		r55	0939.60		nsf	
b31	0118.95		b07	0425.12	nc	b26	0762.31	13,14		b06	0901.45	nc			r49	0940.26		b03	
b26	0119.29	05,15	b07	0426.20	10,18	b25	0762.96	12,15		r55	0901.62		nsf		r46	0940.73		nsf	
b05	0129.82	nc	b05	0426.93	08,18	b01	0772.39	13,09		b26	0901.78	15,15			r48	0941.93		b14	
b08	0132.23	08,23	b09	0429.37	10,15	b03	0773.23	nc		b03	0904.34		nsf		b16	0942.00		nsf	
b06	0134.87	08,15	b31	0432.59		b02	0780.59	nc		b06	0904.35		nsf		r34	0942.03		b05	
b09	0140.43	08,17	b04	0440.75	13,15	b31	0780.79			r46	0904.90		nsf		b15	0942.14		nsf	
b25	0148.04	07,20	b27	0441.35	09,18	b02	0781.01	nc		r41	0906.51		nsf		b27	0942.26		nsf	
b10	0150.18	09,21	b26	0443.46	06,15	b07	0784.78	11,13		b05	0906.53		nsf		b03	0942.32		nsf	
b08	0151.15	08,22	b08	0447.51	12,17	b03	0784.89	12,14		b09	0906.70		nsf		b06	0942.34		r33	
b07	0151.28	06,20	b09	0450.06	11,16	b09	0801.76	13,16		r33	0907.78		nsf		r37	0942.68		b05	
b04	0154.01	06,16	b03	0454.75	08,19	b02	0802.65	13,10		b05	0908.92	14,14			r33	0942.92		nsf	
b01	0156.04	04,15	b25	0468.42	11,17	b10	0809.21	16,15		r52	0909.51		b08		b13	0943.09		r33	
b27	0156.89	05,17	b09	0468.95	12,16	b04	0815.56	17,12		b01	0909.98		nsf		r45	0943.31		nsf	
b05	0159.54	07,19	b02	0471.06	10,11	b26	0817.23	14,14		r54	0910.39		nsf		b25	0943.57		nsf	
b25	0160.37	07,19	b26	0472.17	09,15	b25	0824.51	13,16		r47	0910.50		nsf		b05	0943.62		nsf	
b09	0163.70	09,18	b01	0474.06	09,13	b05	0826.14	13,15		r37	0910.59		nsf		r52	0944.57		b10	
b04	0166.89	07,16	b06	0475.92	13,16	b01	0827.25	nc		b13	0911.00		nsf		r42	0947.71		b05	
b02	0167.04	07,15	b05	0481.81	09,18	b31	0832.92			r34	0911.73		nsf		r36	0948.20		b05	
b26	0171.95	06,16	b01	0487.71	09,12	b07	0836.12	12,13		b07	0911.89		nsf		r54	0948.39		b16	
b08	0175.90	08,21	b05	0493.25	10,18	b02	0837.01	13,09		b14	0911.96		r40		r47	0948.50		b16	
b10	0176.84	10,20	b31	0493.50		b03	0838.85	13,14		b15	0912.25		r40		r38	0948.82		b14	
b31	0177.51		b10	0494.28	13,20	b01	0844.40	14,09		b06	0913.09	13,15			r51	0948.93		b14	
b03	0186.21	05,19	b04	0496.31	14,14	b04	0857.90	16,11		b04	0913.17		r40		r35	0949.37		b03	
b31	0191.56		b09	0498.79	11,15	r42	0857.96		nsf	r45	0913.18		b01		b07	0949.51		r33	
b06	0191.90	09,15	b03	0500.34	09,18	r50	0858.00		nsf	b27	0913.26		r40		b10	0949.57		nsf	
b01	0194.45	05,14	b07	0511.18	10,17	r51	0858.03		nsf	r36	0913.65		nsf		r56	0949.90		b16	
b27	0197.32	nc	b10	0514.89	14,19	b11	0858.28		nsf	b12	0913.89		nsf		b26	0951.07		r35	
b09	0198.98	09,17	b26	0516.07	10,14	b03	0858.31		nsf	b16	0914.07		r40		b12	0951.85		r33	
b04	0202.98	nc	b02	0522.76	11,10	b26	0858.32		nsf	r35	0914.07		b04		r44	0952.10		b06	
b25	0205.23	nc	b27	0523.12	10,17	r52	0858.40		nsf	r56	0914.14		b01		r48	0952.96		b14	
b10	0208.98	11,20	b08	0525.46	13,16	b10	0858.43		nsf	b26	0915.18		nsf		r34	0953.06		b05	
b04	0215.95	07,17	b25	0534.04	nc	b07	0858.46		nsf	b25	0916.01		r40		b06	0953.37		r33	
b08	0219.96	09,21	b10	0541.78	15,19	r37	0858.54		nsf	r42	0916.46		b08		b11	0953.53		r36	yes
b25	0223.89	07,18	b05	0545.09	11,17	b15	0858.59		nsf	r40	0916.62		b08		r39	0953.65		b16	yes
b27	0227.15	06,18	b06	0545.71	14,16	b04	0858.75		nsf	b11	0916.82		nsf		r43	0953.90		nsf	
b08	0239.62	10,21	b31	0548.56		r39	0858.78		nsf	r38	0917.42		nsf		r50	0954.12		b14	
b26	0241.67	07,15	b08	0548.68	12,15	b12	0858.84		nsf	r50	0917.42		nsf		b13	0954.26		r33	
b06	0243.95	09,14	b25	0548.79	12,16	r53	0858.85		nsf	r51	0917.53		nsf		r37	0955.15		b05	yes
b31	0248.43		b01	0554.93	10,12	r43	0858.92		nsf	b10	0917.84		r40		b17	0955.51		r33	yes
b02	0249.09	08,14	b07	0556.10	11,17	r55	0859.03		nsf	r44	0918.32		b08	yes	b09	0955.79		r37	
b01	0250.06	06,15	b31	0559.01		r45	0859.20		nsf	r39	0919.67		nsf		r53	0956.21		nsf	
b05	0254.00	07,18	b10	0559.67	16,18	b17	0859.21		nsf	r43	0919.92		nsf		b02	0956.25		r37	
b09	0255.45	08,16	b10	0571.31	15,17	r47	0859.31		nsf	b02	0920.07		nsf		r49	0956.46		b03	
b07	0259.84	07,19	b02	0575.48	12,10	b27	0859.62		nsf	r53	0920.29		b04		r41	0957.25		nsf	
b25	0261.79	08,17	b09	0577.65	12,16	r34	0859.65		nsf	b17	0920.50		nsf		r52	0958.15		b10	
b03	0262.90	06,20	b27	0585.87	11,16	r35	0859.67		nsf	r55	0920.62		b01		b14	0958.20		nsf	
b04	0263.64	08,16	b03	0588.85	10,18	r38	0860.12		nsf	r49	0921.26		nsf		r55	0958.60		b14	
b08	0270.10	11,20	b26	0594.85	11,15	b08	0860.18		nsf	r48	0922.93		nsf		r46	0959.73		b14	yes
b10	0274.45	12,21	b07	0595.31	12,16	b07	0860.25	13,14		b03	0923.34		r40		b15	0961.14		r35	
b31	0280.56		b01	0597.57	11,11	b05	0860.32		nsf	b06	0923.35		r33		b27	0961.26		r35	
b31	0288.98		b05	0605.20	11,18	b25	0860.35		nsf	r46	0923.90		b01	yes	b03	0961.32		r35	
b04	0293.93	09,15	b04	0615.53	15,13	b14	0860.46		nsf	r45	0924.31		nsf		r56	0962.25		nsf	
b26	0298.10	08,15	b25	0618.26	13,17	r44	0860.68		nsf	r41	0925.51		b04		r45	0962.31		nsf	

b25	0962.57		nsf	
r48	0964.60		nsf	
r54	0964.96		nsf	
r34	0965.54		nsf	
r51	0965.60		nsf	
r47	0965.70		nsf	
b06	0965.85		nsf	
r38	0966.03		nsf	
r42	0966.18		nsf	
r35	0966.42		b03	yes
b07	0966.56		nsf	
b13	0966.98		nsf	
b26	0967.03		r35	
b02	0967.79		r37	yes
b12	0967.81		nsf	
r49	0968.00		nsf	
r44	0968.06		b06	
r50	0968.34		nsf	
b10	0968.57		r42	
b17	0969.50		nsf	
r52	0969.62		b10	
r39	0969.73		nsf	
r55	0970.07		nsf	
b11	0970.48		nsf	
r46	0971.20		nsf	
b15	0972.60		r35	yes
r43	0972.90		nsf	
b09	0973.54		nsf	
r53	0975.21		b07	
r41	0976.25		b07	
b27	0976.82		nsf	
b25	0981.57		r42	
b26	0982.01		nsf	
r52	0982.03		b10	
b02	983.20		nsf	
r44	0983.46		b06	
r34	0984.54		nsf	
r51	0984.60		nsf	
b06	0984.85		r42	
r42	0985.18		nsf	
b07	0985.56		r42	
b13	0985.98		r42	
b12	0986.81		r42	
r49	0987.00		b07	
b10	0987.00		r42	
b31	0987.39			
b17	0988.50		nsf	
b11	0989.48		r42	
b15	0989.60		nsf	
r41	0989.78		b07	
r43	0991.90		b07	
r53	0992.21		b07	
b09	0992.54		r42	
b07	0993.32	nc		
b25	0995.10		r42	
b27	0995.82		r42	
r49	0998.81		b07	
r52	0999.71		b10	
b12	1000.17		r42	
b07	1000.73		r42	yes
r49	0897.42	nc		
r49	0912.46	nc		
r54	0937.15	22,06		
r49	0939.93	22,02		
r48	0957.64	21,09		
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b13	1000.92		nsf	
r41	1000.96		b07	yes
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r44	1001.15		b06	
b02	1002.20		nsf	
b06	1002.54		nsf	
b11	1003.35		nsf	
r34	1003.54		nsf	
r51	1003.60		nsf	
r53	1004.15		nsf	
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r43	1004.76		nsf	
r38	1004.98		nsf	
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b25	1006.79		nsf	
b17	1007.50		nsf	
b15	1008.60		nsf	
r56	1010.35		nsf	
r55	1012.60		nsf	
r44	1013.65		b06	yes
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r49	1017.35		nsf	
r52	1018.26		b10	
r50	1018.42		nsf	
b12	1018.71		nsf	
b10	1019.87		r51	
b13	1019.92		r51	
b26	1020.01		r52	

b02	1021.20		r51	
r46	1021.32		nsf	
b11	1022.35		r51	
r34	1022.54		nsf	
r39	1022.57		nsf	
r51	1022.60		nsf	
r45	1022.62		nsf	
r53	1023.15		nsf	
b09	1023.23		r51	
r43	1023.76		nsf	
r48	1024.48		nsf	
r44	1025.54		nsf	
b25	1025.79		r51	
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b15	1027.60		r51	
r47	1027.60		nsf	
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b27	1033.37		r51	
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r34	1041.54		b15	
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r43	1042.76		b15	
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b12	1051.92		r52	
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b17	1054.78		r51	
b15	1054.92		r51	
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r34	1055.75		b15	
r51	1055.81		b15	
r43	1056.00		b15	
r54	1056.82		nsf	
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r38	1060.95		nsf	
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r56	1065.81		nsf	
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b17	1068.87		r51	
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b12	1077.34		r52	
r50	1079.40		nsf	
b25	1079.50		r51	
b17	1080.20		r51	

r39	1081.26	nc		
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b13	1085.03		r51	
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r44	1088.73		b10	
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r51	1088.90		b10	
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r41	1093.81		b10	
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b10	1096.31		r51	
b13	1096.35		r51	
b26	1096.45		r52	
b02	1097.64		r51	
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r43	1098.28		b10	yes
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b27	1099.51		r51	
b11	1099.60		r51	
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b09	1100.48		r51	
r53	1100.70		nsf	
b12	1100.89		r52	
r44	1100.95		nsf	
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r51	1104.57		nsf	
b25	1106.90		r51	
b17	1107.60		r51	
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r45	1112.62		nsf	
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r53	1119.70		b26	
r44	1119.95		b26	
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b09	1130.10		r51	
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r53	1134.51		b26	
r44	1134.76		b26	
r34	1134.87		b26	
r47	1135.12		nsf	
r39	1135.93		nsf	
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b17	1137.23		r51	
r51	1138.39		b26	
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b26	1144.84		r52	
r49	1144.87		b26	
b09	1144.92		r51	
b12	1145.32		r52	
r54	1145.46		nsf	

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b27	1147.90		r51
b26	1147.96	15,14	
r53	1149.32		b26
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b25	1151.34		r51
r48	1151.95		b26
b17	1152.04		r51
r55	1152.68	nc	
r51	1153.20		b26
r41	1158.51		b26
b11	1158.85		r51
b02	1159.00	14,09	
b13	1159.56		r51
b26	1159.65		r52
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r54	1164.46		b27
r34	1164.50		b26
r52	1165.59		b27
r43	1165.67		b26
b25	1166.15		r51
r48	1166.76		b26
b17	1166.85		r51
r51	1168.01		b26
r56	1168.54		nsf
r38	1172.12	nc	
r41	1173.32		b26
r46	1173.59		nsf
b11	1173.67		r51
b13	1174.37		r51
b26	1174.46		r52
r49	1174.50		b26
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b12	1174.95		r52
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b02	1175.65		r51
r39	1177.32		nsf
b27	1177.53		r51
r53	1178.95		b26
r44	1179.20		b26
r54	1179.28		b27
r34	1179.31		b26
r52	1180.40		b27
r43	1180.48		b26
b25	1180.96		r51
r48	1181.57		b26
b17	1181.67		r51
r50	1182.20		nsf
r51	1182.82		b26
r55	1184.01	20,10	
r41	1188.14		b26
b11	1188.48		r51
r38	1188.98		nsf
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b26	1189.28		r52
r49	1189.31		b26
b09	1189.35		r51
b12	1189.76		r52
b02	1190.46		r51
b27	1192.34		r51
r53	1193.76		b26
r44	1194.01		b26
r54	1194.09		b27
r34	1194.12		b26
r52	1195.21		b27
r43	1195.29		b26
b25	1195.78		r51
r48	1196.39		b26
r47	1196.46		nsf
b17	1196.48		r51
r51	1197.64		b26
r51	1199.17	19,07	
r54	1200.25	20,07	
r39	1202.76	23,06	
r41	1202.95		b26
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r38	1203.48	22,06	
b13	1204.00		r51
b26	1204.09		r52
r49	1204.12		b26
r53	1204.15	nc	
b09	1204.17		r51
b12	1204.57		r52
r53	1204.59	18,04	
b02	1205.28		r51

b27	1207.15		r51	
r53	1208.57		b26	
r44	1208.82		b26	
r54	1208.90		b27	
r34	1208.93		b26	
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r43	1210.10		b26	
b25	1210.59		r51	
r48	1211.20		b26	
b17	1211.29		r51	
r51	1212.45		b26	
r41	1217.76		b26	
b11	1218.10		r51	
b13	1218.81		r51	
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r51	1227.26		b26	
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r38	1231.67		nsf	
r56	1231.89		nsf	
r41	1232.57		b26	
b11	1232.92		r51	
b13	1233.62		r51	
b26	1233.71		r52	
r49	1233.75		b26	
b09	1233.79		r51	
b12	1234.20		r52	
r46	1234.32		nsf	
b02	1234.90		r51	
b27	1236.78		nsf	
r53	1238.20		b26	
r44	1238.45		b26	
r54	1238.53		b27	
r34	1238.56		b26	
r52	1239.65		b27	
r43	1239.73		b26	
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b17	1240.92		r51	
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b02	1249.71		r51	
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r44	1253.26		b26	
r54	1253.34		b27	
r34	1253.37		b26	
r52	1254.46		b27	
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b27	1255.78		r38	
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r41	1262.20		b26	
b11	1262.54		r51	
b13	1263.25		r51	
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r49	1263.37		b26	
b09	1263.42		r51	
b12	1263.82		r52	
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r38	1265.48		b2	
r53	1267.82		b26	

r44	1268.07		b26	
r54	1268.15		b27	
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b25	1269.84		r51	
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b27	1270.59		r38	
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b11	1277.35		r51	
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b27	1285.40		r38	
r51	1286.51		b26	
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r41	1291.82		b26	
b11	1292.17		r51	
b13	1292.87		r51	
r49	1293.00		b26	
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r52	1298.90		b27	
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b27	1299.18		nsf	
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b26	1310.93		nsf	
r53	1311.23		b26	
r44	1311.48		b26	
r54	1311.56		b27	
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r43	1311.73		b26	
b02	1312.12		nsf	
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r52	1313.25		b27	
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b11	1673.85		r52	
b13	1674.56		r52	
r49	1675.54	nc		
r41	1677.23		b26	
b26	1677.62		r52	
r49	1678.50		b26	
b12	1678.95		r52	
r50	1679.10	21,08		
r50	1679.23		nsf	
r39	1680.03		b26	
b25	1680.12		r52	
b02	1680.87		r39	yes
r52	1681.37	nc		
b17	1681.39		r52	
r54	1683.90	21,09		
b09	1686.09		nsf	
b27	1686.14		nsf	
b25	1686.25	15,12		
r41	1689.87	nc		
r53	1689.96		b26	
r44	1690.21		b26	
r34	1690.32		b26	

r43	1690.46		b26
r52	1691.98		b27
b11	1692.28		r52
r55	1692.96		nsf
b13	1692.98		r52
r41	1695.65		b26
b26	1696.04		r52
r49	1696.92		b26
b12	1697.37		r52
r49	1698.34	nc	
b25	1698.54		r52
r56	1698.71	nc	
b02	1699.29		nsf
b17	1699.81		r52
r56	1700.87		nsf
r54	1701.64		nsf
r49	1703.68	nc	
b09	1705.09		r52
r45	1705.75		nsf
r53	1706.29		b26
r44	1706.54		b26
r56	1706.64	21,09	
r34	1706.65		b26
r43	1706.79		b26
r53	1707.82	nc	
r52	1708.31		b27
r52	1708.51	nc	
b11	1708.60		r52
b26	1708.78	18,16	
b13	1709.31		r52
r41	1709.84	nc	
r41	1711.98		b26
b26	1712.37		r52
r48	1713.00		nsf
r49	1713.25		b26
b12	1713.70		r52
b25	1714.87		r52
r41	1716.00	nc	
b17	1716.14		r52
b02	1718.29		r52
r46	1718.64		nsf
r51	1719.42	16,07	
r47	1720.51		nsf
r50	1721.28		nsf
b09	1721.42		r52
r53	1722.62		b26
r44	1722.87		b26
r34	1722.98		b26
r43	1723.12		b26
r53	1724.14	16,05	
r52	1724.64		b27
b11	1724.93		r52
b27	1725.54	17,14	
b13	1725.64		r52
r41	1728.31		b26

b26	1728.70		r52
r49	1729.57		b26
b12	1730.03		r52
b27	1730.10		nsf
b25	1731.20		r52
r49	1731.71	nc	
b17	1732.46		r52
b02	1734.62		r52
r52	173[illegible].99	23,04	
b09	1737.75		r52
r53	1738.95		nsf
r44	1739.20		b26
r34	1739.31		b26
r43	1739.45		b26
r52	1740.96		b27
b11	1741.26		
b13	1741.96		[illegible]
r41	1744.64		b26
r41	1745.01	nc	
b26	1745.03		r52
r49	1745.90		b26
b12	1746.35		r52
r49	1746.85	nc	
b25	1747.53		r52
r41	1748.46	22,02	
b09	1748.50	nc	
b17	1748.79		r52
r55	1748.93		nsf
b27	1749.10		r52
r49	1749.21	nc	
r54	1749.65		nsf
r49	1749.78	nc	
b02	1750.95		r52
r47	1753.12		nsf
b09	1754.07		r52
r56	1754.50		nsf
r44	1755.53		b26
r34	1755.64		b26
r43	1755.78		b26
r46	1756.79		nsf
r48	1757.17		nsf
r52	1757.29		b27
b11	1757.59		r52
r45	1757.90		nsf
b13	1758.29		r52
r40	1760.31	nc	
r41	1760.96		b26
b26	1761.35		r52
r49	1762.23		b26
b12	1762.68		r52
b09	1762.87	nc	
b25	1763.85		r52
r50	1764.70	20,07	
b17	1765.12		r52
b27	17[illegible].43		r52

b02	176[illegible].28		r52
r48	1769.98	22,05	
b09	1770.40		r52
r50	1771.31		b26
r44	1771.85		b26
r34	1771.96		b26
r40	1772.00	nc	
r43	1772.10		b26
r52	1773.62		b27
b11	1773.92		r52
b09	1774.37	nc	
b13	1774.62		r52
r49	1776.04	nc	
r41	1777.29		b26
b26	1777.69		r52
r49	1778.56		b26
b12	1779.01		r52
b25	1780.19		r52
b17	1781.45		r52
b27	1781.75		r52
b02	1783.01	nc	
b02	1783.60		r52
r40	1785.00	22,05	
r54	1786.25		nsf
r37	1786.42	22,02	
b09	1786.73		r52
r53	1787.04		nsf
r50	1787.64		b26
r44	1788.19		b26
r34	1788.29		b26
r43	1788.43		b26
r55	1789.17	20,09	
r52	1789.95		b27
b11	1790.25		r52
b13	1790.95		r52
r41	1793.62		b26
b02	1793.81	19,09	
b26	1794.01		r52
r49	1794.89		b26
b12	1795.34		r52
b25	1796.51		r52
r55	1796.70		nsf
b17	1797.78		r52
b27	1798.09		nsf
b09	1798.45	17,16	

Annex D2

SHORT-FORM PRINT-OUT OF 50 BLUE MEDIUM TANK BATTLES

In all the print-outs the R No. is the random number selected as the point from which the battle begins. For key to print-outs see "Format for Results" in App C.

```
R No.   01744275
Battle 1

r41  696 20, 5|b06 12,10 1
b16  703  1,11|r47 20, 9 2
b08  708 14,17|r33 17, 5 2
b04  721 14,14|r44 21, 4 3
r40  729 21, 4|b14  5, 7 2
b17  729  2, 4|r43 20, 7 1
b12  736  2, 4|r45 20, 8 2
r36  739 20, 5|b06 12,10 2
r42  746 23, 3|b15  6,23 3
b11  762  2, 5|r46 18,10 4
b10  762 18,20|r43 20, 7 1
b09  773 14,14|r44 21, 4 2
b15  815  6,23|r44 21, 4 2
r35  824 20, 7|b07 17,14 1
r37  826 23, 4|b03 12,12 2
r34  863 17, 4|b01  9,17 2
r43  880 20, 7|b13  3, 3 4
b06  907 14,11|r38 23, 7 2
r39  963 23, 6|b07  8,14 1
b02  994 15,14|r33 17, 6 2
r38 1068 22, 7|b07 18,133
b11 r10 hit
```

```
R No.   22245676
Battle 2

r49  000 23, 3|b31  0, 0 8
r49  215 23, 3|b31  0, 0 4
r49  499 23, 3|b31  0, 0 2
r53  778 20, 5|b31  0, 0 8
r51  904 20, 7|b31  0, 0 8
b16  965  1,11|r46 18,10 2
b10  973 17,14|r34 17, 4 2
r42  983 23, 3|b15  6,23 2
r41  989 20, 5|b05 15,15 2
b03  997 17,10|r36 20, 5 2
b17  998  2, 4|r47 20, 9 2
b12 1001  2, 4|r39 23, 6 2
b09 1002 15,15|r33 17, 5 2
r40 1002 21, 4|b02 14,15 2
r33 1006 17, 5|b14  5, 7 3
b08 1007 18,17|r35 20, 7 2
b11 1012  2, 5|r46 18,10 2
b14 1034  5, 7|r43 20, 7 4
b01 1037 12,16|r44 21, 4 4
r35 1037 20, 7|b05 15,15 2
r50 1042 23, 7|b31  0, 0 8
b07 1051 14,17|r34 17, 4 4
r34 1127 17, 4|b15  6,23 2
r37 1165 22, 2|b13  3, 3 5
r36 1284 20, 5|b15  6,23 9
r39 1407 22, 5|b05 18,13 2
b04 1555 14,14|r38 22, 7 3
b12 r9 hit
```

```
R No.   22450327
Battle 3

r56  220 18,10|b31  0, 0 10
r54  486 23, 6|b31  0, 0 8
r48  823 20, 8|b31  0, 0 8
r56  908 18.10|b31  0, 0 6
b05  961 12, 9|r45 20, 8 1
b02  965 17,12|r43 20, 7 1
r34  970 17, 4|b12  2, 4 2
r37  991 23, 4|b16  1,11 2
b13  996  3, 3|r46 18,10 2
b06 1002 14,15|r35 20, 7 2
b10 1003 13,15|r40 21, 4 2
r42 1003 23, 3|b14  5, 7 2
r55 1040 20, 9|b31  0, 0 10
b15 1041  6,23|r36 20, 5 2
r38 1618 22, 6|b01 18,10 2
b6 r4 hit
```

```
R No.   07557127
Battle 4

r55  156 20, 9|b31  0, 0 1C
r50  612 23, 7|b31  0, 0 8
r35  667 20, 7|b03 13,12 2
b17  668  2, 4|r45 20, 8 2
b07  676 14,16|r40 21, 4 2
r34  686 17, 4|b14  5, 7 2
b11  695  2, 5|r43 20, 7 2
b02  717  7,16|r42 23, 3 2
b03  718 12,13|r41 20, 5 3
r49  719 23, 3|b31  0, 0 8
b16  721  1,11|r46 18,10 3
r40 1612 21, 4|b04 14,15 3
r41 1655 18, 4|b04 14,15 2
r38 1683 21, 6|b01 15,10 2
r33 1703 16, 6|b10 14,14 6
b04 1706 15,15|r36 18, 6 2
r37 1722 22, 4|b05 20,17 4
r36 1724 18, 5|b09 17,14 6
r39 1741 23, 4|b01 15,10 3
r43 1750 20, 7|b10 14,14 2
b01 1775 15,10|r46 18,10 1
b8 r10 hit
```

```
R No.   05542710
Battle 5

r55  067 20, 9|b31  0, 0 10
r50  518 23, 7|b31  0, 0 8
b01  813 14,11|r34 17, 4 1
r41  829 20, 5|b09 12,15 2
b11  871  2, 5|r45 20, 8 2
r33  834 17, 5|b10 17,14 2
b09  845 12,15|r44 21, 4 3
b02  845 11,12|r42 23, 3 2
r36  847 20, 5|b06 13,11 2
b07  853 12, 9|r47 20, 9 1
b04  856 14,14|r43 20, 7 2
r34  862 17, 4|b03 15,10 1
r42  874 23, 3|b05 17,20 2
b10  883 18,13|r44 21, 4 1
b13  887  3, 3|r35 20, 7 3
b06  908 14,12|r43 20, 7 1
r39  908 23, 6|b03 15,10 2
r40  961 22, 4|b14  5, 7 2
r37 1008 23, 3|b15  6,23 6
r35 1028 20, 7|b12  2, 4 2
r45 1040 20, 8|b16  1,11 8
r38 1117 22, 7|b03 17,10 2
b03 1156 17,10|r46 18,10 1
b27 1470 18,10|r46 18,10 7
b27 1520 18,10|r46 18,10 0
b10 r11 hit
```

```
R No.   05115054
Battle 6

r53  682 20, 5|b31  0, 0 8
r54  757 23, 6|b31  0, 0 8
r54  803 23, 6|b31  0, 0 4
r49  853 23, 3|b31  0, 0 8
r40  986 21, 4|b11  2, 5 2
b06  989 13,11|r47 20, 9 1
b07 1000 18, 9|r45 20, 8 2
r35 1006 20, 7|b10 16,16 2
b08 1010 17,16|r44 21, 4 2
r39 1015 23, 6|b02 14,15 2
b15 1018  6,23|r37 23, 4 3
r43 1023 20, 7|b11  2, 5 1
b13 1036  3, 3|r47 20, 9 2
b03 1051 14,15|r36 20, 5 2
b11 1053  2, 5|r41 20, 5 5
b12 1073  2, 4|r46 18,10 4
b17 1087  2, 4|r36 20, 5 1
b05 1416 16,17|r38 22, 7 4
```

```
r38 1429 22, 7|b01  9,19 3
b10 r5 hit
```

```
R No.   25220553
Battle 7

r55  045 20, 9|b31  0, 0 1C
r49  234 23, 3|b31  0, 0 8
r37  880 23, 4|b12  2, 4 2
b07  882 12,15|r40 21, 4 2
b03  886 15,16|r34 17, 4 2
b14  888  5, 7|r39 23, 6 2
b05  900  9,18|r33 17, 5 2
r36  901 20, 5|b10 17,16 2
b04  906 18,11|r35 20, 7 1
b12  910  2, 4|r46 18,10 2
b02  913 13,14|r41 20, 5 2
r34  923 17, 4|b17  2, 4 4
r35  926 20, 7|b08 13,18 4
b11 1013  2, 5|r45 20, 8 5
r54 1013 23, 6|b31  0, 0 8
b13 1041  3, 3|r46 18,10 5
b16 1047  1,11|r45 20, 8 1
b17 1137  2, 4|r39 23, 6 10
b26 1277 18,11|r46 18,10 9
b26 1306 18,11|r46 18,10 2
b26 1373 19,11|r56 19,11 1
b26 1385 19,11|r56 19,11 0
r39 1491 22, 6|b10 18,13 6
b01 1503 12,15|r33 17, 5 8
b12 r5 hit
```

```
R No.   11141127
Battle 8

r51  035 20, 7|b31  0, 0 8
r49  651 23, 3|b31  0, 0 8
r50  711 23, 7|b31  0, 0 8
b04  864 12,15|r44 21, 4 1
r36  875 20, 5|b09 17,12 2
b12  881  2, 4|r47 20, 9 1
b11  883  2, 5|r39 23, 6 2
b10  887 16,15|r42 23, 3 2
b05  892 13,13|r33 17, 5 2
r37  894 23, 4|b08 14,16 2
b06  904 16,15|r35 20, 7 2
r42  910 23, 3|b09 17,12 1
r40  915 21, 4|b16  1,11 3
b08  924 14,16|r43 20, 7 3
b07  934 14,11|r35 21, 7 1
b16  948  1,11|r45 20, 8 2
r39  980 23, 6|b09 18,13 2
b01  996 14,10|r45 20, 8 2
b13 1010  3, 3|r38 23, 7 6
b09 1028 17,12|r41 20, 5 7
r41 1030 20, 5|b15  6,23 4
b14 1061  5, 7|r38 23, 7 2
b17 1066  2, 4|r47 20, 9 8
r34 1190 17, 4|b15  6,23 6
r33 1301 16, 3|b15  6,23 6
b03 1365 12,13|r35 20, 7 5
r38 1425 22, 6|b02 18,14 9
r45 1475 20, 8|b15  6,23 6
r35 1545 20, 8|b15  6,23 1
r46 1593 18,10|b15  6,23 2
b15 r12 hit
```

```
R No.   05547417
Battle 9

r49  022 23, 3|b31  0, 0 8
r49  238 23, 3|b31  0, 0 4
r49  521 23, 3|b31  0, 0 2
r53  801 20, 5|b31  0, 0 8
r51  926 20, 7|b31  0, 0 8
r37  977 23, 4|b12  2, 4 2
```

```
b06  990 16,14|r36 20, 5 1
b16  993  1,11|r34 17, 4 3
r42  994 23, 3|b13  3, 3 2
r41  999 20, 5|b10 15,16 2
b12 1001  2, 4|r45 20, 8 3
r33 1002 17, 5|b03 17,14 2
b14 1013  5, 7|r47 20, 9 2
b11 1016  2, 5|r39 23, 6 3
b10 1028 15,16|r34 17, 3 1
b01 1039  8,17|r36 20, 5 2
b07 1059 16,14|r44 21, 4 7
r35 1059 20, 7|b08 13,15 2
r40 1089 21, 4|b17  2, 4 2
r34 1089 18, 3|b03 18,13 4
b09 1091 12,13|r36 20, 5 3
b05 1097 14,12|r44 21, 4 1
r39 1387 22, 5|b04 16,11 2
r38 1455 22, 6|b02 13,13 9
r36 1578 20, 5|b15  6,23 5
b10 r10 hit
```

```
R No. 11321055
Battle 10

b08  918 12,15|r44 21, 4 1
b01  923 13, 8|r46 18,10 1
r53  925 20, 5|b31  0, 0 8
b04  926 16,11|r33 17, 5 1
r40  930 21, 4|b16  1,11 2
r36  953 20, 5|b11  2, 5 2
b16  953  1,11|r39 23, 6 2
b05  955 14,14|r37 23, 4 3
r33  955 17, 5|b17  2, 4 2
b14  959  5, 7|r46 18,10 1
b03  966 14,15|r35 20, 7 2
r37  967 23, 4|b02 12, 8 3
r35  972 20, 7|b15  6,23 2
r42 1000 23, 3|b07 13,14 2
b07 1000 13,14|r41 20, 5 3
b06 1013  3,15|r44 21, 4 5
b15 1062  6,23|r41 20, 5 3
b10 1098 16,15|r43 20, 7 2
r38 1298 22, 6|b02 15, 8 2
r51 1503 17, 6|b02 17, 7 12
r51 1517 17, 6|b02 17, 7 9
r51 1531 17, 6|b02 17, 7 6
r51 1558 17, 6|b02 17, 7 3
r51 1601 17, 6|b02 17, 7 0
r51 1617 17, 7|b02 17, 7 0
r39 1680 22, 6|b02 18, 8 2
b11 r8 hit
```

```
R No.   02440337
Battle 11

r51  553 20, 7|b31  0, 0 8
r49  595 23, 3|b31  0, 0 8
r33  979 17, 5|b11  2, 5 2
b01  982 13,14|r40 21, 4 2
b12 1000  2, 4|r46 18,10 3
b09 1001 18,14|r44 21, 4 1
r35 1014 20, 7|b14  5, 7 2
b03 1016 15,16|r36 20, 5 3
r41 1018 20, 5|b15  6, 3 2
b10 1034 15,16|r34 17, 4 3
b16 1038  1,11|r39 23, 6 4
b02 1056 14,15|r42 23, 3 4
r34 1066 17, 4|b17  2, 4 5
r36 1066 20, 5|b06 12,14 2
r42 1073 23, 3|b13  3, 3 3
r37 1104 23, 4|b07 18,13 3
r39 1234 23, 6|b07 18,14 2
r51 1685 20, 6|b04 20, 6 6
r51 1710 20, 6|b04 20, 6 3
r51 1750 20, 6|b04 20, 6 0
r51 1765 20, 6|b04 20, 6 0
b7 r8 hit
```

R No. 00613470
Battle 12

r53 124 20, 5	b31 0, 0 8
r49 181 23, 3	b31 0, 0 8
r56 251 18,10	b31 0, 0 10
r54 456 23, 6	b31 0, 0 8
r50 725 23, 7	b31 0, 0 8
r36 931 20, 5	b10 14,18 2
b15 941 6,23	r44 21, 4 2
b17 942 2, 4	r47 20, 9 1
b10 950 14,18	r41 20, 5 2
r42 966 23, 3	b05 14,14 2
b16 967 1,11	r43 20, 7 2
r37 976 23, 4	b09 15,17 3
b04 979 17,11	r33 17, 5 2
b05 986 14,14	r40 21, 4 2
b13 994 3, 3	r35 20, 7 2
b07 994 15,15	r44 21, 4 2
r39 1548 22, 6	b08 15,15 2

b8 r4 hit

R No. 17253314
Battle 13

r41 764 20, 5	b10 17,18 2
b12 782 2, 4	r39 23, 6 3
b14 782 5, 7	r33 17, 5 2
r35 788 20, 7	b04 12,10 1
b09 807 11,15	r44 21, 4 4
b02 810 10,17	r40 21, 4 3
b17 816 2, 4	r38 23, 7 2
b03 818 16,11	r43 20, 7 2
b11 826 2, 5	r46 18,10 2
b15 827 6,23	r34 17, 4 2
r56 842 18,10	b31 0, 0 10
b04 902 14, 9	r46 18,10 1
b07 902 13,15	r37 23, 4 3
b16 924 1,11	r38 23, 7 2

b11 r2 hit

R No. 27352717
Battle 14

r55 759 20, 9	b31 0, 0 10
r40 917 21, 4	b02 15,13 2
b13 920 3, 3	r38 23, 7 2
b09 920 13,13	r42 23, 3 2
b15 922 6,23	r34 17, 4 2
b17 932 2, 4	r45 20, 8 2
r35 940 20, 7	b04 18,11 1
b08 945 14,15	r43 20, 7 1
r41 949 20, 5	b10 15,16 2
b03 953 12,12	r34 17, 4 1
b01 966 11,16	r44 21, 4 2
r33 983 17, 5	b02 15,13 2

b7 r4 hit

R No. 10521130
Battle 15

r48 500 20, 8	b31 0, 0 8
r56 554 18,10	b31 0, 0 10
r41 715 20, 5	b07 15,12 2
b06 717 11,13	r44 21, 4 2
b07 737 15,12	r37 23, 4 2
b11 740 2, 5	r43 20, 7 3
r34 751 17, 4	b04 13,11 2
r35 751 20, 7	b14 5, 7 2
b17 764 2, 4	r45 20, 8 4
b09 772 14,13	r42 23, 3 3
b02 792 13,14	r36 20, 5 3
b14 798 5, 7	r47 20, 9 1
b15 801 6,23	r40 21, 4 6
b03 832 14,15	r43 20, 7 2
r39 1468 22, 5	b04 17, 9 2
b04 1472 17, 9	r36 20, 5 2
r38 1519 22, 6	b01 12,16 4

b10 r5 hit

R No. 01623755
Battle 16

r49 166 23, 3	b31 0, 0 8
b12 789 2, 4	r45 20, 8 1
r34 790 17, 4	b10 15,11 2
r36 794 20, 5	b08 10,23 2
r42 816 23, 3	b04 9,15 2
r37 818 23, 4	b11 2, 5 2
b02 827 12,15	r33 17, 5 2
r41 836 20, 5	b10 15,11 2
b17 845 2, 4	r45 20, 8 3
b04 845 10,14	r35 20, 7 3
b05 849 13,21	r44 21, 4 4
b06 879 17,13	r33 17, 5 2
b10 888 15,11	r35 20, 7 2
b14 890 5, 7	r46 18,10 2
b09 922 14,14	r35 20, 7 1

b15 935 6,23	r44 21, 4 3
r38 1039 22, 7	b08 19,21 3

b10 r6 hit

R No. 26202426
Battle 17

r49 292 23, 3	b31 0, 0 8
r35 743 20, 7	b06 13,17 2
b12 746 2, 4	r45 20, 8 2
b03 759 14,14	r33 17, 5 2
b08 766 15,15	r42 23, 3 2
b05 767 12,16	r44 21, 4 2
r37 772 23, 4	b11 2, 5 3
b17 772 2, 4	r39 23, 6 3
b09 777 14,16	r36 20, 5 2
b16 785 1,11	r47 20, 9 2
r40 797 21, 4	b07 14,13 3
r33 801 17, 5	b10 13,15 3
b06 808 14,17	r41 20, 5 2
b15 814 6,23	r34 17, 4 2
b04 825 13,18	r44 21, 4 3
b01 828 11,11	r36 20, 5 2
r36 834 20, 5	b14 5, 7 2
b10 843 13,15	r42 23, 3 2
r42 851 23, 3	b13 3, 3 2
r38 1209 22, 6	b02 14,14 3

b12 r7 hit

R No. 03047244
Battle 18

r52 859 21, 4	b31 0, 0 8
b03 967 17,15	r43 20, 7 1
b12 968 2, 4	r45 20, 8 2
b07 981 12,10	r47 20, 9 1
b10 984 15,13	r44 21, 4 3
r42 1006 23, 3	b16 1,11 3
b08 1010 11,15	r40 21, 4 2
b13 1016 3, 3	r45 20, 8 2
b05 1017 14,15	r37 23, 4 2
b14 1019 5, 7	r38 23, 7 3
r53 1027 20, 5	b31 0, 0 8
b09 1032 14,16	r44 21, 4 2
r35 1045 20, 7	b11 2, 5 6
r40 1061 21, 4	b15 6,23 6
r36 1066 20, 5	b04 16,13 2
r34 1090 17, 4	b01 12,15 4
r39 1098 23, 6	b02 13,16 5
r41 1108 20, 5	b11 2, 5 3
r33 1120 17, 5	b04 17,12 2
r37 1156 22, 4	b04 17,12 1
r38 1415 22, 8	b06 17,16 2
b27 1581 18,11	r46 18,10 9
b27 1609 18,11	r46 18,10 2
b27 1642 18,11	r46 18,10 0
b27 1655 18,11	r46 18,10 0

b9 r10 hit

R No. 00467703
Battle 19

r53 818 20, 5	b31 0, 0 8
b16 834 1,11	r47 20, 9 1
b06 846 17,15	r42 23, 3 2
b15 848 6,23	r41 20, 5 2
b17 866 2, 4	r46 18,10 1
r36 869 20, 5	b13 3, 3 2
b14 875 5, 7	r34 17, 4 2
b04 883 11,12	r33 17, 5 2
r37 906 23, 4	b11 2, 5 4
b12 910 2, 4	r39 23, 6 2
b05 918 13,14	r34 17, 4 2
b07 922 13,14	r42 23, 3 2
r40 1009 21, 4	b13 3, 3 2
r33 1048 17, 5	b11 2, 5 2
r35 1075 21, 7	b13 3, 3 3
r41 1114 20, 5	b11 2, 5 3
r39 1768 22, 7	b08 15,12 1

b9 r7 hit

R No. 27207172
Battle 20

r55 289 20, 9	b31 0, 0 10
r49 429 23, 3	b31 0, 0 8
b06 871 13,15	r37 23, 4 2
r34 875 17, 4	b12 2, 4 2
r42 880 23, 3	b14 5, 7 2
b02 886 15,19	r44 21, 4 2
b12 890 2, 4	r38 23, 7 2
r41 894 20, 5	b07 15,15 2
b04 906 14,16	r33 17, 5 3
b17 918 2, 4	r47 20, 9 4
b09 925 18,18	r36 20, 5 3
r36 932 20, 5	b13 3, 3 2
b05 939 11,14	r44 21, 4 2

b10 970 15,15	r40 21, 4 2
r37 975 23, 4	b16 1,11 2
b15 1011 6,23	r44 21, 4 4

b9 r5 hit

R No. 02043503
Battle 21

r42 756 23, 3	b01 9,17 2
b14 764 5, 7	r39 23, 6 2
r40 775 21, 4	b16 1,11 2
r35 779 20, 7	b03 15,17 3
b09 780 15,17	r41 20, 5 2
b13 784 3, 3	r43 20, 7 2
r34 788 17, 4	b05 12,12 2
b06 788 12,15	r36 20, 5 2
b10 802 12,15	r44 21, 4 5
b11 807 2, 5	r38 23, 7 4
r36 812 20, 5	b12 2, 4 2
r41 813 20, 5	b17 2, 4 3
b12 817 2, 4	r45 20, 8 3
b08 848 11,12	r43 20, 7 3
b07 865 19,16	r44 21, 4 3
b04 876 14,16	r37 23, 4 3
b02 923 11,19	r33 17, 5 9
b03 971 15,16	r37 23, 4 2
r39 1073 21, 6	b05 13,10 2
r38 1235 22, 7	b01 12,17 10

b12 r8 hit

R No. 23421164
Battle 22

r54 518 23, 6	b31 0, 0 8
r55 729 20, 9	b31 0, 0 10
r36 753 20, 5	b10 15,21 2
b05 754 14,15	r34 17, 4 2
b04 755 15,10	r46 18,10 1
b01 763 10,12	r40 21, 4 2
r33 768 17, 5	b17 2, 4 2
b06 778 18,17	r42 23, 3 4
b13 790 3, 3	r47 20, 9 4
r35 803 20, 7	b02 12,12 3
r40 804 21, 4	b10 15,21 2
b15 810 6,23	r44 21, 4 2
b03 818 11,13	r43 20, 7 3
b14 824 5, 7	r41 20, 5 4
r37 826 23, 4	b12 2, 4 4
b12 848 2, 4	r39 23, 6 3
b17 855 2, 4	r38 23, 7 3
b08 855 18,21	r42 23, 3 2
r39 1055 22, 6	b07 14,16 3
r38 1394 22, 7	b02 14,10 1
b09 1445 14,15	r41 19, 3 6

b12 r7 hit

R No. 10247421
Battle 23

r54 156 23, 6	b31 0, 0 8
r52 643 21, 4	b31 0, 0 8
r37 899 23, 4	b03 17,10 2
b05 906 12,15	r36 20, 5 2
b15 914 6,23	r34 17, 4 2
b14 924 5, 7	r38 23, 7 3
r35 931 20, 7	b01 14,15 2
b03 934 17,10	r41 20, 5 3
r36 942 20, 5	b09 14,15 2
b13 943 3, 3	r39 23, 6 3
b04 961 15,13	r44 21, 4 2
b11 973 2, 5	r38 23, 7 2
b09 1058 14,15	r41 20, 5 2
r34 1091 18, 5	b06 10,15 5
r33 1146 18, 4	b06 10,15 2
b10 1237 14,14	r42 22, 4 6
r41 1254 20, 5	b08 13,16 17
r42 1307 22, 4	b02 12, 8 2
r46 1327 18,10	b08 14,16 1
r40 1425 21, 4	b02 13, 9 2
b06 1793 14,15	r38 22, 7 2

b10 r9 hit

R No. 05221367
Battle 24

r48 100 20, 8	b31 0, 0 8
r36 848 20, 5	b03 14,16 2
b09 849 14,13	r33 17, 5 1
b01 859 8,16	r41 20, 5 3
r41 859 20, 5	b02 14,16 2
b12 861 2, 4	r47 20, 9 2
b14 871 5, 7	r46 18,10 3
b04 884 14,14	r33 17, 5 1
b06 889 14,15	r44 21, 4 3
b17 897 2, 4	r45 20, 8 4
r49 903 23, 3	b31 0, 0 8
b13 928 3, 3	r33 17, 5 2

b07 936 13,13	r40 21, 4 2
r35 939 20, 7	b10 17,13 2
b16 956 1,11	r47 20, 9 5
r37 957 23, 4	b11 2, 5 3
r34 962 17, 4	b03 15,17 4
r40 973 21, 4	b05 16,15 5
r42 976 23, 4	b02 14,16 3
b05 1008 16,15	r44 21, 4 2
r45 1107 20, 8	b02 15,16 5
r39 1400 22, 5	b10 18,11 3
r48 1420 20, 7	b26 19, 7 5

b11 r9 hit

R No. 17520114
Battle 25

r51 000 20, 7	b31 0, 0 8
r55 048 20, 9	b31 0, 0 10
r55 231 20, 9	b31 0, 0 6
r48 271 20, 8	b31 0, 0 8
r48 326 20, 8	b31 0, 0 4
r53 580 20, 5	b31 0, 0 8
r36 631 20, 5	b07 16,13 1
b01 787 14,15	r44 21, 4 2
b03 789 14,15	r34 17, 4 2
b13 797 3, 3	r38 23, 7 3
r35 803 20, 7	b09 11,17 2
r37 805 23, 4	b15 6,23 2
b06 820 12,12	r40 21, 4 3
b08 824 18,16	r43 20, 7 1
b16 834 1,11	r45 20, 8 2
r43 835 20, 7	b11 2, 5 2
r34 842 17, 4	b02 13,12 1
r42 843 23, 3	b07 17,14 2
r33 845 17, 5	b04 13,10 2
b11 856 2, 5	r46 18,10 5
r40 889 21, 4	b07 17,14 2
b05 913 11,17	r44 21, 4 6
b02 956 13,12	r41 20, 5 2
b10 998 17,20	r44 21, 4 4
b04 1039 15,12	r41 21, 4 2
r38 1212 21, 7	b07 19,15 3

b11 r9 hit

R No. 10034545
Battle 26

r54 279 23, 6	b31 0, 0 8
r48 853 20, 8	b31 0, 0 8
r41 942 20, 5	b02 14,10 1
b12 948 2, 4	r34 17, 4 2
b09 960 17,15	r42 23, 3 2
r35 974 20, 7	b05 18,11 2
b08 996 14,15	r43 20, 7 2
b03 1010 14,15	r34 17, 4 3
r34 1030 17, 4	b10 14,15 2
b02 1035 13,11	r47 20, 9 2
b14 1035 5, 7	r46 18,10 2
b16 1036 1,11	r39 23, 6 3
b07 1042 13,15	r43 20, 7 2
r33 1049 17, 5	b06 15,17 2
r42 1062 23, 3	b11 2, 5 2
b17 1074 2, 4	r38 23, 7 2
b05 1083 19,12	r37 22, 3 1
b13 1089 3, 3	r46 18,10 2
b11 1090 2, 5	r45 20, 8 5
r37 1100 22, 3	b10 14,15 2
r36 1169 20, 5	b06 16,15 7
b10 1366 15,12	r39 23, 4 2
r39 1377 23, 4	b01 16,12 2
b26 1643 20, 7	r45 20, 8 9
b26 1645 20, 7	r54 20, 7 6
b26 1679 20, 7	r54 20, 7 3
b06 1680 18,16	r38 22,10 2
b26 1686 20, 7	r45 20, 8 0

b14 r8 hit

R No. 26446147
Battle 27

r51 208 20, 7	b31 0, 0 8
b01 854 15,11	r36 20, 5 1
r36 862 20, 5	b07 12,14 2
b04 887 15,15	r33 17, 5 2
b06 890 11,11	r43 20, 7 2
b17 891 2, 4	r47 20, 9 2
r41 893 20, 5	b09 12,15 2
b09 894 12,15	r42 23, 3 [illegible]
b10 895 13,15	r34 17, 4 2
r33 906 17, 5	b02 14,16 2
r37 908 23, 4	b07 12,14 2
r42 925 23, 3	b08 19,15 3
b05 926 12,15	r40 21, 4 5
b02 937 14,16	r43 20, 7 2
r34 962 17, 4	b13 3, 3 2
b14 980 5, 7	r39 23, 6 2
b11 984 2, 5	r38 23, 7 2
b16 1018 1,11	r47 20, 9 3

b13 1035 3, 3|r39 23, 6 2
b12 1080 2, 4|r39 23, 6 2
r39 1444 22, 7|b07 13,12 2
b08 1448 18,13|r40 21, 3 3
r40 1520 21, 3|b03 16,13 10
r38 1587 23, 6|b03 16,13 3
b14 r9 hit

R No. 24132031
Battle 28
r53 179 20, 5|b31 0, 0 8
r55 418 20, 9|b31 0, 0 10
r55 948 20, 9|b31 0, 0 6
b13 960 3, 3|r47 20, 9 1
b15 972 6,23|r44 21, 4 1
b14 979 5, 7|r33 17, 5 2
r41 991 20, 5|b11 2, 5 3
b02 993 14,10|r39 23, 6 1
b01 1001 14,16|r40 21, 4 2
r37 1011 23, 4|b17 2, 4 3
b11 1013 2, 5|r46 18,10 3
r42 1020 23, 3|b12 2, 4 4
b10 1026 15,13|r43 20, 7 1
b07 1027 15,12|r33 17, 5 2
b05 1059 15,16|r44 21, 4 3
r33 1068 17, 5|b16 1,11 2
r40 1113 21, 4|b04 15,15 4
r34 1122 17, 4|b16 1,11 2
r36 1130 20, 5|b06 13, 7 3
r35 1170 20, 7|b08 14,15 2
b09 1196 12,15|r44 21, 4 2
b03 1405 14,15|r39 22, 6 2
b11 r8 hit

R No. 15532301
Battle 29
r51 682 20, 7|b31 0, 0 8
r36 743 20, 5|b13 3, 3 2
b04 747 13,15|r37 23, 4 2
b14 762 5, 7|r38 23, 7 2
r42 762 23, 3|b02 9,14 2
b09 767 14,14|r34 17, 4 2
b15 769 6,23|r35 20, 7 2
r49 770 23, 3|b31 0, 0 8
r41 787 20, 5|b08 12,15 2
r35 791 20, 7|b07 14,15 2
b11 793 2, 5|r39 23, 6 2
b03 807 13,15|r44 21, 4 2
b06 809 14,15|r33 17, 5 2
b10 811 18,21|r40 21, 4 2
b13 908 3, 3|r45 20, 8 4
b12 923 2, 4|r47 20, 9 5
b16 939 1,11|r46 18,10 2
b17 974 2, 4|r46 18,10 1
r48 1052 20, 8|b31 0, 0 8
r38 1323 22, 6|b02 13,10 2
b26 1728 17,10|r46 18,10 9
b26 1757 17,10|r46 18,10 2
b26 1784 17,10|r46 18,10 0
b26 1797 17,10|r46 18,10 0
b12 r5 hit

R No. 14541473
Battle 30
r48 464 20, 8|b31 0, 0 8
r52 573 21, 4|b31 0, 0 8
r56 621 18,10|b31 0, 0 10
b09 703 16,15|r43 20, 7 1
b12 706 2, 4|r45 20, 8 1
r33 715 17, 5|b16 1,11 2
b01 729 12,16|r44 21, 4 2
b03 734 14,14|r43 20, 7 1
r42 737 23, 3|b13 3, 3 2
r35 740 20, 7|b06 13,12 2
b10 740 12,12|r40 21, 4 2
r41 747 20, 5|b02 13,18 3
b14 748 5, 7|r46 18,10 2
b13 774 3, 3|r38 23, 7 4
b04 784 11,15|r43 20, 7 2
b15 786 6,23|r37 23, 4 2
r54 832 23, 6|b31 0, 0 8
b9 r4 hit

R No. 13465443
Battle 31
r55 420 20, 9|b31 0, 0 10
r35 687 20, 7|b06 11,11 1
b08 690 10,17|r43 20, 7 2
b03 703 10,12|r44 21, 4 2
b17 717 2, 4|r46 18,10 3
r40 718 21, 4|b12 2, 4 2
r33 719 17, 5|b06 11,11 1
b01 736 8,13|r43 20, 7 2
b16 737 1,11|r47 20, 9 3

b06 747 11,11|r45 20, 8 1
b13 755 3, 3|r46 18,10 1
b14 769 5, 7|r41 20, 5 2
b07 859 13,15|r43 20, 7 2
r39 1607 22, 6|b02 13,10 1
r38 1785 22, 8|b09 18,11 1
b9 r5 hit

R No. 02653712
Battle 32
r52 213 21, 4|b31 0, 0 8
r55 408 20, 9|b31 0, 0 10
r53 680 20, 5|b31 0, 0 8
r49 705 23, 3|b31 0, 0 8
r48 765 20, 8|b31 0, 0 8
r35 869 20, 7|b07 15,15 1
b03 870 15,11|r45 20, 8 2
b02 878 16,13|r33 17, 5 1
b07 885 15,15|r36 20, 5 2
b15 890 6,23|r37 23, 4 2
r33 904 17, 5|b17 2, 4 2
r34 906 17, 4|b10 10,14 2
r37 907 23, 4|b13 3, 3 3
b05 911 12,15|r43 20, 7 2
b11 914 2, 5|r39 23, 6 2
r41 916 20, 5|b08 13,15 2
r36 941 20, 5|b16 1,11 2
b01 967 12,16|r42 23, 3 8
b04 976 14,15|r43 20, 7 3
b09 1000 14,15|r44 21, 4 2
b9 r6 hit

R No. 00100530
Battle 33
r50 196 23, 7|b31 0, 0 8
r53 859 20, 5|b31 0, 0 8
r34 971 17, 4|b17 2, 4 2
b13 981 3, 3|r33 17, 5 2
b15 981 6,23|r42 23, 3 2
r42 995 23, 3|b12 2, 4 2
b06 998 11,13|r40 21, 4 2
b01 1001 12,13|r44 21, 4 1
r40 1003 21, 4|b14 5, 7 2
b02 1004 15,14|r35 20, 7 3
b16 1005 1,11|r38 23, 7 3
b10 1026 16,17|r43 20, 7 2
b04 1026 17,11|r37 23, 4 2
r33 1049 17, 5|b17 2, 4 2
r36 1049 20, 5|b03 15, 9 2
b08 1061 18,15|r44 21, 4 3
b09 1078 15,16|r35 22, 7 2
r41 1084 20, 5|b12 2, 4 5
b05 1105 11,15|r37 23, 4 3
r38 1262 22, 7|b03 15, 9 2
b11 r7 hit

R No. 20010764
Battle 34
r55 256 20, 9|b31 0, 0 10
r50 298 23, 7|b31 0, 0 8
r52 434 21, 4|b31 0, 0 8
r33 755 17, 5|b07 10,11 1
b12 774 2, 4|r38 23, 7 2
b01 775 14,14|r44 21, 4 2
r34 777 17, 4|b03 16,11 1
b06 789 11,15|r36 20, 5 2
b02 822 13,12|r43 20, 7 1
b07 828 10,11|r35 20, 7 4
r39 832 23, 6|b04 15,10 2
b03 856 17,10|r46 18,10 1
r42 861 23, 3|b13 3, 3 2
r35 862 20, 7|b08 12,15 3
r41 866 21, 4|b11 2, 5 2
b11 870 2, 5|r47 20, 9 2
r40 876 21, 4|b15 6,23 2
b14 895 5, 7|r45 20, 8 4
b16 933 1,11|r47 20, 9 3
b05 1000 13,15|r37 23, 4 3
r37 1011 23, 4|b08 12,15 9
b17 1033 2, 4|r47 20, 9 5
r45 1143 20, 8|b13 3, 3 9
b13 1257 3, 3|r38 23, 7 2
r36 1282 20, 5|b15 6,23 22
b08 1419 11,13|r38 22, 6 3
r38 1447 22, 6|b04 18, 9 2
b13 r11 hit

R No. 17227732
Battle 35
r35 975 20, 7|b17 2, 4 2
b16 975 1,11|r39 23, 6 2
b04 986 12, 9|r38 23, 7 2
b15 992 6,23|r42 23, 3 2
b12 1008 2, 4|r47 20, 9 3

b03 1009 12,15|r33 17, 5 4
b11 1015 2, 5|r34 17, 4 3
r36 1017 20, 5|b13 3, 3 3
b13 1030 3, 3|r46 18,10 4
b09 1051 17,16|r44 21, 4 2
b07 1052 14,14|r43 20, 7 1
r41 1093 20, 5|b14 5, 7 4
r40 1099 21, 4|b05 14,15 2
b14 1110 5, 7|r47 20, 9 2
r37 1130 23, 4|b02 17,10 2
b06 1135 14,11|r38 23, 7 1
b02 1139 17,10|r56 18,10 1
b17 1156 2, 4|r39 23, 6 2
r39 1590 22, 5|b10 17,13 2
r38 1623 22, 6|b10 17,13 1
b10 1655 17,12|r42 22, 2 3
b14 r7 hit

R No. 11132156
Battle 36
r48 252 20, 8|b31 0, 0 8
b04 796 13,14|r33 17, 5 2
b14 800 5, 7|r46 18,10 2
r42 813 23, 3|b10 14,15 2
b06 818 13,12|r43 20, 7 2
b02 830 17,14|r34 17, 4 2
b08 834 12,19|r44 21, 4 3
r36 836 20, 5|b03 14,12 1
b10 845 14,15|r37 23, 4 3
b13 862 3, 3|r33 17, 5 2
r34 872 17, 4|b09 17,14 2
b11 880 2, 5|r46 18,10 4
r40 902 21, 4|b03 15,13 3
b12 904 2, 4|r47 20, 9 6
r38 1422 21, 7|b03 16,12 1
b27 1589 21, 8|r35 21, 7 9
b27 1614 21, 8|r35 21, 7 2
b27 1650 21, 8|r35 21, 7 0
b27 1668 21, 8|r35 21, 7 0
b9 r5 hit

R No. 14244367
Battle 37
r56 582 18,10|b31 0, 0 10
r50 779 23, 7|b31 0, 0 8
r51 810 20, 7|b31 0, 0 8
b05 864 15,13|r34 17, 4 1
r37 865 23, 4|b04 14,14 2
b11 871 2, 5|r38 23, 7 2
r41 884 20, 5|b12 2, 4 2
r33 886 17, 5|b17 2, 4 2
b09 887 12,14|r44 21, 4 2
b01 895 15,12|r42 23, 3 3
r35 907 20, 7|b06 17,13 2
b03 913 13,15|r34 17, 4 2
b15 944 6,23|r43 20, 7 3
b12 959 2, 4|r46 18,10 3
b10 970 17,19|r36 20, 5 3
b08 985 8,16|r44 21, 4 2
b16 1001 1,11|r39 23, 6 4
b17 1028 2, 4|r46 18,10 3
b14 1061 5, 7|r45 20, 8 8
b13 1080 3, 3|r39 23, 6 4
b06 1576 18,10|r38 22, 6 2
b14 r4 hit

R No. 20550613
Battle 38
r41 583 20, 5|b09 12,15 2
b17 608 2, 4|r45 20, 8 3
r35 608 20, 7|b15 6,23 2
b01 621 8,16|r33 17, 5 4
r37 625 23, 4|b05 10,17 3
r42 626 23, 3|b14 5, 7 2
b08 636 11,16|r44 21, 4 4
r34 637 17, 4|b10 10,13 3
b16 639 1,11|r38 23, 7 4
b12 642 2, 4|r43 20, 7 4
r33 644 17, 5|b13 3, 3 2
r40 646 21, 4|b02 14,15 4
b15 658 6,23|r36 20, 5 2
b05 680 10,16|r44 21, 4 2
b09 688 12,15|r43 20, 7 2
b03 724 13,12|r44 21, 4 2
r36 740 20, 5|b11 2, 5 2
b10 776 12,11|r43 20, 7 3
b02 807 14,15|r43 20, 7 1
r39 884 23, 6|b07 9,17 3
r38 934 22, 7|b06 14,16 7
b11 r10 hit

R No. 25456144
Battle 39
r41 742 20, 5|b05 13,11 1

b11 746 2, 5|r47 20, 9 2
b06 751 14,15|r43 20, 7 2
b09 765 15,15|r33 17, 5 2
r42 774 23, 3|b13 3, 3 2
b13 785 3, 3|r46 18,10 3
b10 791 15,16|r34 17, 4 2
b15 800 6,23|r44 21, 4 4
b12 861 2, 4|r47 20, 9 2
b01 874 11,11|r39 23, 6 3
r46 893 18,10|b14 5, 7 2
b16 898 1,11|r45 20, 8 3
b05 923 14,10|r47 20, 9 2
b14 984 5, 7|r38 23, 7 3
b17 1026 2, 4|r39 23, 6 2
r37 1473 23, 4|b07 13,14 2
b04 1549 14,15|r36 20, 5 3
r36 1552 20, 5|b07 13,13 4
r34 1638 16, 2|b07 13,13 4
b13 r6 hit

R No. 22357202
Battle 40
r37 735 23, 4|b12 2, 4 2
b15 741 6,23|r41 20, 5 2
b06 755 12,12|r40 21, 4 2
b12 759 2, 4|r43 20, 7 2
r36 771 20, 5|b14 5, 7 2
r35 777 20, 7|b04 9,14 3
b17 777 2, 4|r46 18,10 4
b07 803 11,13|r42 23, 3 2
b11 834 2, 5|r39 23, 6 3
b08 835 13,17|r40 21, 4 4
b03 844 12,13|r41 20, 5 4
b04 855 9,14|r44 21, 4 5
r42 858 23, 3|b13 3, 3 2
b05 882 9,12|r33 17, 5 2
r34 891 17, 4|b14 5, 7 3
b16 919 1,11|r47 20, 9 2
b13 920 3, 3|r39 23, 6 2
b09 942 18,21|r41 20, 5 3
b02 984 14,13|r40 21, 4 2
b01 1018 11,19|r33 17, 5 4
b10 1031 16,15|r40 21, 4 2
b14 1181 5, 7|r43 20, 7 9
b17 r5 hit

R No. 06037160
Battle 41
r54 479 23, 6|b31 0, 0 8
r48 516 20, 8|b31 0, 0 8
r54 815 23, 6|b31 0, 0 4
r42 877 23, 3|b12 2, 4 2
b15 886 6,23|r44 21, 4 1
b05 896 11,17|r40 21, 4 2
b17 897 2, 4|r38 23, 7 2
b13 897 3, 3|r39 23, 6 2
r37 901 23, 4|b03 17,11 2
r33 906 17, 5|b07 12, 9 1
b14 926 5, 7|r47 20, 9 1
b10 931 13,15|r44 21, 4 2
b16 966 1,11|r45 20, 8 2
b01 967 10,19|r44 21, 4 1
r45 983 20, 8|b03 18,11 2
r39 989 23, 6|b04 13,13 2
r35 991 20, 7|b09 15,15 2
r40 1001 21, 4|b08 16,17 2
r36 1007 20, 5|b02 14,16 2
r34 1023 16, 3|b07 12, 9 3
r41 1046 20, 5|b11 2, 5 2
r38 1145 23, 7|b06 17,17 2
b8 r11 hit

R No. 14107412
Battle 42
r52 080 21, 4|b31 0, 0 8
r49 352 23, 3|b31 0, 0 8
r41 837 20, 5|b07 14, 9 1
b17 852 2, 4|r47 20, 9 1
r42 852 23, 3|b13 3, 3 2
b08 855 17,21|r36 20, 5 2
r39 865 23, 6|b04 15, 9 1
b07 871 14, 9|r46 18,10 1
r40 873 21, 4|b06 12,12 2
b11 881 2, 5|r35 20, 7 2
r37 883 23, 4|b14 5, 7 2
b13 892 3, 3|r43 20, 7 3
b05 893 10,14|r44 21, 4 2
b10 905 18,14|r33 17, 5 1
b09 943 14,16|r35 20, 7 3
b06 968 12,12|r33 17, 5 1
r38 1545 22, 6|b01 16,15 2
r33 1634 17, 5|b04 19,10 1
r36 1703 20, 5|b02 18, 4 1
r35 1770 20, 7|b04 20,10 1
b9 r9 hit

```
R No.   20246165
Battle 43
r51  807 20, 7|b31  0, 0 8
r35  955 20, 7|b09 15,15 1
b16  961  1,11|r46 18,10 2
b05  966 13,15|r42 23, 3 2
r33  972 17, 5|b03 15, 9 2
b15  975  6,23|r44 21, 4 2
b03  981 15, 9|r47 20, 9 1
b01  998 15,11|r34 17, 4 2
r37  998 23, 4|b07 17,20 2
b17 1002  2, 4|r45 20, 8 4
b6 r3 hit
```

```
R No.   05057542
Battle 44
b01  962 16,11|r47 20, 9 1
b10  981 16,14|r33 17, 5 2
r35  986 20, 7|b12  2, 4 2
r34  992 17, 4|b13  3, 3 2
r33  996 17, 5|b15  6,23 2
b17  998  2, 4|r46 18,10 2
b06 1009 15,14|r37 23, 4 3
b05 1010 13,19|r44 21, 4 3
b15 1019  6,23|r40 21, 4 4
b12 1028  2, 4|r47 20, 9 1
r40 1032 21, 4|b11  2, 5 2
b09 1033 15,15|r43 20, 7 1
b03 1036 17,12|r36 20, 5 3
r37 1056 23, 4|b13  3, 3 3
b02 1080 17,13|r43 20, 7 2
r42 1091 23, 3|b14  5, 7 2
r41 1100 20, 5|b16  1,11 2
r36 1103 20, 5|b08 14,15 2
b08 1142 14,15|r44 21, 4 3
r38 1653 22,10|b04 15, 9 1
r39 1769 23, 7|b07 17,11 1
b11 r10 hit
```

```
R No.   17622331
Battle 45
r48  157 20, 8|b31  0, 0 8
b10  716 16,15|r33 17, 5 2
b07  717 13,15|r42 23, 3 2
b06  717 12,10|r45 20, 8 2
b12  722  2, 4|r46 18,10 1
r42  724 23, 3|b17  2, 4 2
b14  729  5, 7|r34 17, 4 2
r41  740 20, 5|b13  3, 3 2
b09  761 14,17|r44 21, 4 2
r56  802 18,10|b31  0, 0 10
r40  823 21, 4|b04 11,10 2
r36  836 20, 5|b17  2, 4 2
r34  853 17, 4|b04 11,10 1
b03  857 15,13|r35 20, 7 2
r33  903 17, 5|b01 10,16 4
r37  911 23, 4|b08 10,16 3
r35  941 20, 7|b17  2, 4 6
r38  999 22, 7|b04 11,11 3
b05 1256  9,14|r39 22, 6 5
r39 1270 22, 6|b08 12,18 2
b26 1429 18,12|r56 18,12 11
b26 1447 18,12|r56 18,12 7
b26 1458 18,12|r56 18,12 4
b26 1476 18,12|r56 18,12 2
b26 1592 17,11|r56 17,11 0
b26 1605 17,11|r56 17,11 0
b8 r10 hit
```

```
R No.   24772231
Battle 46
r53  359 20, 5|b31  0, 0 8
r51  596 20, 7|b31  0, 0 8
b04  949 12, 9|r46 18,10 1
r36  957 20, 5|b10 14,16 2
b15  957  6,23|r44 21, 4 1
r34  970 17, 4|b03 16,12 2
b17  986  2, 4|r38 23, 7 2
r48  993 20, 8|b31  0, 0 8
b01  997 15,17|r35 20, 7 2
r33  999 17, 5|b16  1,11 2
b02 1014 11,16|r43 20, 7 4
b14 1084  5, 7|r38 23, 7 2
b13 1088  3, 3|r47 20, 9 2
b11 1125  2, 5|r39 23, 6 2
b12 1143  2, 4|r38 23, 7 3
b16 1262  1,11|r46 18,10 11
r38 1547 22, 4|b10 17,15 2
r40 1584 20, 3|b03 16,12 4
r41 1586 19, 4|b05 17,11 3
r42 1608 23, 3|b09 16,15 2
r35 1619 22, 6|b03 16,12 1
b03 1666 17,11|r46 18,10 1
r37 1722 23, 2|b10 18,13 2
r39 1767 23, 5|b07 16,14 3
b05 1794 17,11|r46 18,10 1
b12 r10 hit
```

```
R No.   02764714
Battle 47
r48  003 20, 8|b31  0, 0 8
b11  700  2, 5|r47 20, 9 2
b01  706  9,16|r43 20, 7 2
r33  708 17, 5|b17  2, 4 2
b13  740  3, 3|r46 18,10 2
b06  743 12,13|r44 21, 4 2
b15  748  6,23|r34 17, 4 2
b16  751  1,11|r38 23, 7 2
b07  766 11,16|r36 20, 5 4
b17  781  2, 4|r35 20, 7 2
b8 r1 hit
```

```
R No.   23272607
Battle 48
r50  175 23, 7|b31  0, 0 8
b13  679  3, 3|r38 23, 7 2
r35  683 20, 7|b15  6,23 2
b16  703  1,11|r46 18,10 2
b11  709  2, 5|r39 23, 6 2
b05  713  8,18|r40 21, 4 4
b02  739  6,18|r34 17, 4 2
b06  762 11,14|r36 20, 5 3
b03  764 12,15|r40 21, 4 2
r53  830 20, 5|b31  0, 0 8
b7 r1 hit
```

```
R No.   23676734
Battle 49
r55  010 20, 9|b31  0, 0 10
r54  309 23, 6|b31  0, 0 8
r48  475 20, 8|b31  0, 0 8
b11  859  2, 5|r39 23, 6 2
b05  859 15,20|r41 20, 5 2
r42  863 23, 3|b06 15,14 2
r35  866 20, 7|b14  5, 7 2
r33  876 17, 5|b03 14,11 2
b10  888 15,15|r44 21, 4 2
b17  891  2, 4|r45 20, 8 2
b13  894  3, 3|r38 23, 7 2
r40  895 21, 4|b12  2, 4 2
b04  904 16,14|r36 20, 5 2
r36  908 20, 5|b03 14,11 1
b01  912 12,16|r43 20, 7 3
r34  915 17, 4|b06 15,14 2
b08  937 17,21|r44 21, 4 2
b03  953 14,10|r37 23, 4 2
r37  959 23, 4|b09 15,16 2
b02 1024  9,16|r43 20, 7 4
r41 1032 20, 5|b12  2, 4 2
r38 1107 22, 7|b09 14,15 2
r39 1673 19, 7|b07,17,11 1
b27 1758 17,10|r46 18,10 9
b10 r10 hit
```

```
R No.   24000326
Battle 50
r50  004 23, 7|b31  0, 0 8
r48  721 20, 8|b31  0, 0 8
b06  966 12,14|r35 20, 7 2
r42  970 23, 3|b15  6,23 2
b10  986 16,16|r43 20, 7 1
r37  991 23, 4|b08 14,15 2
r35  994 20, 7|b07 17,11 1
b02  998 10,15|r40 21, 4 2
b17  998  2, 4|r45 20, 8 2
b13 1001  3, 3|r38 23, 7 4
r34 1002 17, 4|b12  2, 4 2
b05 1019 14,12|r44 21, 4 1
b16 1035  1,11|r45 20, 8 1
b15 1037  6,23|r33 17, 5 3
b03 1077 13,15|r44 21, 4 3
b26 1316 16, 8|r33 16, 7 9
r38 p329 22, 7|b09 16, 9 2
b26 1341 16, 8|r33 16, 7 2
b26 1573 18, 8|r33 17, 8 0
b26 1591 18, 8|r33 17, 8 0
b9 r5 hit
```

Annex D3

LONG-FORM PRINT-OUT OF BATTLE 21
(Blue equipped with hypothetical light tanks)

In the short-form print-out the R No. is the random number selected as the point from which the battle begins. For key to print-outs see "Format for Results" in App C.

SHORT-FORM PRINT-OUT OF BATTLE 21

R No. 13276404

b04	495	13,12	r47	20, 9	1	b07	629	17,12	r39	23, 6	1
r36	500	20,05	b07	16,13	1	r41	630	20,05	b06	13,16	2
r35	508	20,07	b16	1,11	2	r39	630	23,06	b11	2, 5	2
b03	518	12,12	r34	17, 4	1	r33	644	17,05	b08	12,16	4
r38	541	23,07	b17	2, 4	2	b15	656	6,23	r43	20, 7	2
b09	573	18,16	r45	20, 8	1	b08	665	13,15	r47	20, 9	1
b01	593	11,13	r47	20, 9	1	r40	667	21,04	b14	5, 7	2
r42	594	23,03	b02	11,15	2	r34	720	17,04	b06	13,15	2
b10	606	17,15	r43	20, 7	1	r37	768	23,04	b13	3, 3	2
r53	612	20,05	b31	0, 0	8	b9 r10 hit					
b02	620	10,15	r41	20, 5	2						

LONG-FORM PRINT-OUT OF BATTLE 21

b31	0000.00		b10	0089.34	10,22	b25	0183.04	08,21	b04	0281.01	13,15
b09	0000.04	08,19	b04	0090.67	07,18	b02	0189.07	07,17	b26	0282.54	07,16
b10	0000.07	08,23	b07	0091.57	08,16	b08	0191.35	10,21	b09	0284.73	14,16
b27	0000.34	06,18	b27	0092.79	09,17	b31	0192.03		b07	0288.64	13,15
b05	0000.46	04,19	b25	0094.23	09,22	b07	0193.73	11,17	b27	0288.75	14,16
b07	0000.53	05,17	b02	0096.21	06,16	b03	0200.90	08,16	b02	0301.53	07,14
b01	0000.57	03,17	b06	0098.68	07,17	b06	0202.81	10,17	b31	0301.89	
b03	0000.65	05,17	b08	0109.51	08,22	b05	0207.75	07,19	b25	0302.03	12,20
b25	0000.68	07,23	b04	0112.35	08,17	b27	0207.78	12,15	b08	0303.75	09,18
b04	0000.71	05,17	b31	0114.68		b26	0210.15	09,17	b26	0307.57	08,15
b08	0000.75	07,22	b25	0122.40	09,21	b04	0210.21	11,15	b31	0311.56	
b26	0000.81	05,19	b10	0126.04	10,21	b01	0214.32	07,15	b03	0312.14	09,14
b02	0000.87	04,18	b01	0126.12	05,16	b08	0215.21	10,20	b06	0314.68	12,16
b06	0000.89	05,17	b09	0127.29	11,18	b09	0217.39	12,16	b05	0317.15	08,17
b03	0022.96	06,16	b03	0132.01	06,16	b07	0220.56	12,16	b04	0319.26	12,14
b31	0023.35		b08	0132.82	09,22	b25	0220.82	09,21	b07	0322.62	14,14
b27	0026.31	07,18	b26	0133.14	08,19	b10	0232.75	12,20	b25	0335.12	11,19
b26	0033.39	06,19	b07	0135.37	09,16	b02	0235.90	06,16	b31	0335.96	
b05	0033.81	05,19	b06	0141.20	08,18	b01	0238.78	08,15	b09	0338.92	15,16
b01	0037.62	04,17	b27	0141.60	10,16	b04	0240.03	12,14	b26	0339.89	09,14
b09	0039.14	09,19	b05	0141.78	06,20	b25	0240.45	10,21	b10	0340.14	14,19
b02	0039.31	05,17	b01	0145.82	06,16	b09	0241.14	13,15	b03	0341.70	09,13
b25	0039.46	08,23	b10	0149.15	11,21	b31	0242.04		b02	0345.98	08,14
b07	0042.45	06,17	b02	0151.01	07,16	b31	0247.39		b10	0349.43	15,19
b27	0044.48	08,18	b31	0155.85		b05	0250.93	07,18	b05	0350.79	09,17
b06	0047.89	06,18	b04	0157.87	09,16	b26	0255.68	08,17	b08	0355.10	09,17
b10	0049.09	09,22	b31	0160.32		b27	0256.09	13,15	b27	0355.56	14,15
b31	0050.87		b07	0167.35	10,17	b08	0256.90	09,19	b01	0356.82	10,16
b04	0060.96	06,17	b03	0168.34	07,15	b02	0259.04	07,15	b02	0364.65	09,15
b07	0069.67	07,16	b04	0172.57	10,16	b07	0264.51	12,15	b06	0368.25	12,15
b25	0075.32	09,23	b10	0173.57	11,20	b06	0265.21	11,17	b03	0372.37	10,12
b09	0076.07	10,19	b06	0174.25	09,18	b25	0267.29	11,20	b08	0372.42	09,16
b08	0079.67	07,21	b27	0174.95	11,15	b03	0268.25	09,15	b10	0376.90	16,18
b03	0080.03	07,17	b26	0176.18	09,18	b01	0268.98	09,16	b01	0377.29	09,16
b01	0084.29	04,16	b09	0177.98	12,17	b31	0270.89		b31	0379.75	
b26	0086.32	07,19	b01	0179.64	07,16	b10	0277.96	13,19	b26	0380.82	10,14

b09	0386.60	16,16	
b05	0386.98	10,17	
b27	0390.90	ne	
b07	0391.34	15,14	
b25	0400.21	12,20	
b04	0401.23	12,13	
b27	0401.26	15,14	
b10	0401.59	17,17	
b26	0404.35	11,14	
b08	0406.51	10,15	
b02	0412.95	09,16	
b06	0413.95	12,16	
b01	0414.71	10,15	
b03	0421.21	11,12	
b31	0423.29		
b04	0426.89	13,13	
b27	0428.60	15,13	
b10	0431.06	ne	
b17	0431.06		nsf
r45	0431.06		nsf
b15	0431.12		nsf
b03	0431.46		nsf
r39	0431.53		nsf
r53	0431.53		nsf
b10	0431.59		nsf
b07	0431.62		nsf
r49	0431.87		nsf
b04	0431.90		nsf
r46	0431.92		nsf
b12	0432.00		nsf
r48	0432.14		nsf
r55	0432.34		nsf
b26	0432.43	12,15	
r47	0432.68		nsf
b05	0432.68	11,17	
r50	0432.73		nsf
r41	0432.73		nsf
b26	0433.07		nsf
b11	0433.29		nsf
b08	0433.34		nsf
r54	0433.39		nsf
b27	0433.42		nsf
r52	0433.45		nsf
b05	0433.48		nsf
r35	0433.65		nsf
r44	0433.73		nsf
b01	0433.90		nsf
r37	0434.03		nsf
r43	0434.04		nsf
r38	0434.29		nsf
r33	0434.31		nsf
r40	0434.42		nsf
r34	0434.51		nsf
r42	0434.56		nsf
b16	0434.57		nsf
b25	0434.60		nsf
b02	0434.60		nsf
b13	0434.64		nsf
r51	0434.76		nsf
b09	0434.84		nsf
b14	0434.87		nsf
b06	0434.90		nsf
r56	0434.98		nsf
r36	0435.43		nsf
b07	0436.12	ne	
b01	0436.40	11,14	
b02	0437.39	10,15	
b10	0437.79	17,16	
b08	0441.75	11,16	
b09	0443.32	17,15	
b25	0444.26	13,21	
b07	0444.90	16,13	
b27	0455.04	16,13	
b03	0457.21	12,12	
b06	0459.60	ne	
b26	0465.87		nsf
b31	0466.28		
r34	0466.57		nsf
r38	0466.60		nsf
r42	0467.09		nsf
r33	0467.18		nsf
r53	0467.98		nsf
r52	0469.01		nsf
r49	0469.20		nsf
b04	0471.39	13,12	
r35	0472.23		nsf
r37	0472.67		nsf
r39	0472.68		nsf
b12	0473.65		nsf
b16	0475.51		nsf
r50	0475.70		nsf
r55	0476.10		nsf

r54	0476.15		nsf	
r47	0476.21		nsf	
r40	0477.15		nsf	
b02	0477.95		nsf	
r36	0478.20		nsf	
b13	0479.43		nsf	
b09	0481.59		nsf	
b07	0481.62		nsf	
r43	0482.18		nsf	
b26	0484.95		r36	
r34	0485.65		b04	
r38	0485.68		b04	
r42	0486.17		b04	
r33	0486.26		b04	
r45	0486.40		nsf	
r41	0486.76		nsf	
r53	0487.06		b04	
b04	0487.39		nsf	
r52	0488.09		b04	
r51	0488.10		nsf	
r49	0488.28		b04	
r48	0488.53		nsf	
b11	0489.28		nsf	
b08	0489.46		nsf	
b06	0489.46	12,15		
b14	0490.54		nsf	
b15	0490.62		nsf	
r56	0490.62		nsf	
b01	0490.75		nsf	
b17	0490.96		nsf	
r35	0491.31		b04	
b06	0491.70		nsf	
r37	0491.75		b04	
r39	0491.76		b04	
b25	0492.09		nsf	
b12	0492.73		r35	
b05	0493.46		nsf	
b16	0494.59		r35	
r50	0494.78		b04	
r46	0494.90		nsf	
b27	0495.07		nsf	
r55	0495.18		b04	
r54	0495.23		b04	
b03	0495.26		nsf	
b10	0495.28		nsf	
r47	0495.29		b04	yes
r40	0496.23		nsf	
r44	0496.95		nsf	
b02	0497.03		r36	
r36	0497.28		nsf	
r53	0498.46		nsf	
b13	0498.51		r35	
r34	0498.92		nsf	
r38	0498.95		nsf	
r52	0499.09		nsf	
r49	0499.28		nsf	
b26	0499.85		r36	
b09	0500.67		r36	
b07	0500.70		r36	yes
r42	0501.01		nsf	
r43	0501.26		nsf	
r35	0502.23		nsf	
r37	0502.67		nsf	
b12	0504.54		r35	
r33	0504.89		nsf	
r45	0505.48		b03	
r41	0505.84		b03	
r51	0507.18		b03	
r48	0507.60		b03	
b11	0508.35		r35	
b08	0508.54		r35	
b16	0508.87		r35	yes
r39	0509.28		nsf	
b14	0509.62		nsf	
r56	0509.70		b03	
b15	0509.70		nsf	
b01	0509.82		nsf	
b17	0510.04		nsf	
b06	0510.78		nsf	
b26	0510.92		nsf	
b25	0511.17		nsf	
b13	0511.73		nsf	
b05	0512.54		nsf	
r55	0512.78		nsf	
r47	0512.81		nsf	
r54	0512.82		nsf	
r50	0513.43		nsf	
r46	0513.98		b03	
b09	0514.09		nsf	
b07	0514.12		nsf	
b27	0514.15		nsf	
b03	0514.34		nsf	

b10	0514.35		nsf	
b02	0514.54		nsf	
r40	0515.31		b03	
b02	0515.75	11,15		
r44	0516.03		b03	
r53	0517.54		b03	
b12	0517.95		nsf	
r34	0518.00		b03	yes
r38	0518.03		nsf	
r52	0518.17		nsf	
r49	0518.35		nsf	
r51	0518.50		nsf	
r45	0518.71		nsf	
b01	0518.93	11,13		
r42	0520.09		nsf	
b31	0520.32			
r43	0520.34		nsf	
b31	0521.14			
b08	0521.21	ne		
r41	0521.64		nsf	
r37	0521.75		nsf	
r48	0522.21		nsf	
b11	0522.89		nsf	
b08	0523.07		nsf	
r33	0523.96		nsf	
b16	0525.46		nsf	
r46	0527.12		nsf	
r56	0527.68		nsf	
r39	0528.35		nsf	
r40	0528.45		nsf	
r44	0528.68		nsf	
b14	0528.70		r38	
b15	0528.78		r38	
b17	0529.12		r38	
b06	0529.85		r38	
b13	0530.81		r38	
r55	0531.85		nsf	
r47	0531.89		nsf	
r54	0531.90		nsf	
b05	0532.31	11,16		
r50	0532.51		nsf	
r53	0535.39		nsf	
r34	0536.84		nsf	
b12	0537.03		r38	
b26	0539.73	11,14		
b27	0540.20	17,12		
b17	0541.21		r38	yes
b11	0541.96		nsf	
b06	0542.20		nsf	
b10	0543.57	17,15		
b16	0544.54		nsf	
b15	0544.75		nsf	
b31	0545.14			
b07	0546.35	17,12		
b14	0547.54		nsf	
b13	0548.57		nsf	
b12	0549.06		nsf	
b09	0549.32	18,16		
b10	0549.45		nsf	
b08	0549.76	12,16		
b25	0551.10		nsf	
b01	0551.48		nsf	
r51	0552.00		nsf	
b26	0553.64		nsf	
r45	0554.04		nsf	
b17	0557.56		nsf	
b02	0558.96		nsf	
r46	0561.60		nsf	
r33	0561.67		nsf	
r52	0564.09		nsf	
r44	0564.09		nsf	
r56	0564.46		nsf	
r49	0565.78		nsf	
b07	0567.79		nsf	
r37	0568.09		nsf	
r43	0568.39		nsf	
b10	0568.53		r42	
b09	0568.67		nsf	
b25	0568.71	14,20		
b05	0569.46		nsf	
b25	0570.18		nsf	
b01	0570.56		r40	
b27	0570.60		nsf	
r51	0571.07		b09	
b26	0572.71		r40	
r45	0573.12		b09	yes
r40	0573.68		nsf	
r47	0574.35		nsf	
b08	0576.34		nsf	
r42	0576.73		nsf	
b02	0578.04		r42	
r34	0580.28		nsf	

b06	0580.65	13,16		
r46	0580.68		nsf	
r33	0580.75		nsf	
b10	0581.90		r42	
r55	0582.39		nsf	
r41	0583.10		nsf	
r48	0583.15		nsf	
r44	0583.17		nsf	
r52	0583.17		nsf	
r56	0583.54		nsf	
r51	0584.23		nsf	
r49	0584.85		nsf	
b15	0584.93		nsf	
r53	0586.25		nsf	
b07	0586.87		r42	
b01	0586.96		r40	
r37	0587.17		nsf	
r43	0587.46		nsf	
r54	0588.14		nsf	
b05	0588.54		r40	
b26	0588.82		r40	
r45	0589.15		nsf	
b25	0589.26		r39	
b27	0589.68		r34	
r39	0591.65		nsf	
r50	0592.00		nsf	
b06	0592.50		nsf	
r40	0592.76		b01	
b12	0593.10		nsf	
r47	0593.43		b01	yes
b02	0594.07		r42	yes
b17	0594.42		nsf	
b08	0595.42		r33	
b10	0598.54		nsf	
b16	0599.17		nsf	
b07	0599.20		nsf	
r34	0599.35		nsf	
b11	0599.68		nsf	
r46	0599.76		b02	
r33	0599.82		b02	
b14	0600.20		nsf	
b31	0601.28			
r55	0601.46		b07	
r41	0602.18		b02	
r48	0602.23		b02	
r44	0602.25		b02	
r52	0602.25		b02	
r56	0602.62		b02	
r51	0603.31		b02	
r49	0603.93		b02	
b15	0604.01		r41	
b26	0604.82		r40	
r53	0605.32		b07	
b05	0605.59		r40	
b25	0606.12		r39	
r37	0606.25		b10	
b27	0606.54		r34	
r43	0606.54		b10	yes
r54	0607.21		b02	
r45	0608.23		b02	
b13	0609.09		nsf	
r40	0609.54		nsf	
r47	0610.21		nsf	
b02	0610.45	10,15		
r39	0610.73		nsf	
r46	0610.76		b02	
r50	0611.07		b07	
b06	0611.57		r41	
b31	0612.06		r53	yes
b12	0612.18		r41	
b02	0612.50		nsf	
b08	0612.64		r33	
r33	0613.17		b02	
b17	0613.50		r39	
r56	0616.81		b02	
r51	0617.50		b02	
b15	0618.12		r41	
r49	0618.12		b02	
b16	0618.25		r39	
b07	0618.28		r34	
r34	0618.43		b07	
r44	0618.67		b02	
r52	0618.75		b02	
b11	0618.76		r39	
b26	0619.01		r40	
b14	0619.28		r39	
r55	0619.62		b07	
r53	0619.81		b07	
b05	0620.00		r40	
b25	0620.60		r39	
r41	0620.71		b02	yes
r48	0620.84		nsf	

r37	0620.95		nsf		b16	0672.65		nsf		r43	0732.50		b25		r55	0790.81		b25	
b27	0621.32		r34		b25	0672.68		nsf		b25	0733.56		r50		r45	0792.17		b25	
b05	0622.98	11,17			r43	0672.79		nsf		r53	0735.03		b25		r48	0792.21		b25	
r50	0624.15		b07		r53	0674.15		nsf		r48	0735.78	nc			r53	0793.73		b25	
r43	0624.64		nsf		r48	0675.53		nsf		r37	0736.20		b25		r52	0794.04		b27	
r54	0625.39		nsf		r37	0675.56		nsf		r48	0736.40		b25		b06	0796.21		r50	
b17	0626.17		r39		r45	0676.03		nsf		r45	0736.67		b25		r47	0796.70		b25	
r45	0626.20		nsf		b13	0676.42		nsf		r49	0736.90	23,02			r50	0802.25		b25	
r33	0626.73		nsf		b26	0677.71		nsf		b13	0737.89		nsf		r46	0803.12		b25	
b13	0628.17		r39		b17	0679.25		nsf		r52	0738.23		b27		r49	0803.76		b25	
r40	0628.62		b15		b27	0679.51		r34		b26	0738.59		r50		r51	0803.78		b25	
r46	0628.73		nsf		b06	0679.53	13,15			b17	0738.62		nsf		r43	0803.82		b25	
r47	0629.29		b07		b11	0680.40		nsf		b26	0739.23	12,13			r54	0804.40		b25	
r39	0629.81		b07	yes	r50	0680.46		nsf		b11	0741.17		nsf		r44	0804.54		b25	
b06	0630.12		r41	yes	r47	0680.56		nsf		r47	0741.20		b25		r56	0804.93		b25	
b11	0630.12		r39	yes	r54	0682.62		nsf		r50	0741.34		b25		b27	0805.28		r52	
b26	0630.45		r40		r44	0683.31		nsf		r46	0742.53		b25		b05	0807.65		nsf	
b12	0630.73		nsf		r52	0683.43		nsf		r51	0742.87		b25		r55	0807.79		b25	
b08	0631.10		r33		b14	0684.18		nsf		r54	0743.50		b25		r45	0809.07		b25	
r34	0631.39		nsf		r46	0684.40		b25		r44	0743.95		b25		r48	0809.20		b25	
r51	0632.68		nsf		b06	0684.64		nsf		r56	0744.03		b25		r53	0810.71		b25	
r44	0632.95		nsf		r49	0686.65		b25		r55	0744.85		b25		r52	0811.03		b27	
r52	0633.00		nsf		r34	0688.62		b25		r49	0745.09		b25		b06	0813.12		r50	
b15	0633.23		nsf		b05	0688.62		r52		r43	0745.46		b25		r47	0813.60		b25	
b14	0633.29		nsf		r51	0688.96		b25		b14	0745.89		nsf		b12	0816.03		nsf	
r49	0633.31		nsf		r56	0690.12		b25		b25	0746.60		r50		r50	0819.23		b25	
r55	0633.71		nsf		r55	0690.95		b25		b16	0746.87		r37		r46	0820.03		b25	
b27	0634.65	16,11			b25	0691.76		r50		b12	0747.95		r37		r43	0820.73		b25	
r56	0635.15		nsf		r43	0691.87		b25		b05	0748.06		nsf		r49	0820.75		b25	
b27	0635.40		r34		r53	0693.23		b25		r53	0748.07		b25		r51	0820.76		b25	
r53	0636.00		nsf		r48	0694.60		b25		r37	0749.17		b25		r54	0821.39		b25	
b05	0636.10		nsf		r37	0694.64		b25		r48	0749.45		b25		r44	0821.45		b25	
b25	0636.79		nsf		r45	0695.10		b25		r45	0749.64		b25		r56	0821.92		b25	
b16	0636.84		nsf		r50	0695.79	22,08			r52	0751.28		b27		b27	0822.26		r52	
r48	0639.92		b15		b27	0696.15		r34		r48	0751.53	20,09			b16	0823.71		nsf	
r37	0640.03		b15		b26	0696.79		r50		b26	0751.64		nsf		r55	0824.78		b25	
b31	0641.73				r50	0699.54		b25		r47	0754.17		b25		r45	0825.98		b25	
r50	0642.31		nsf		r47	0699.64		b25		r50	0754.39		b25		r48	0826.18		b25	
b26	0643.26		r40		b05	0700.14	12,16			r46	0755.50		b25		r53	0827.70		b25	
b06	0643.50		nsf		r46	0700.96		b25		r51	0755.92		b25		r52	0828.01		b27	
r43	0643.71		b15		r54	0701.70		b25		r53	0755.98	nc			b25	0829.78		nsf	
b08	0644.25		r33	yes	r44	0702.39		b25		r54	0756.54		b25		b06	0830.03		r50	
b17	0644.25		nsf		r52	0702.51		b25		r44	0756.92		b25		r51	0830.17	21,04		
r54	0644.46		nsf		r49	0703.29		b25		b13	0756.96		r37		b17	0830.35		nsf	
b08	0644.87	13,15			b06	0703.71		r34		r56	0757.07		b25		r47	0830.51		b25	
r45	0645.28		b15		b05	0705.18		nsf		b17	0757.70		r37		b11	0833.71		nsf	
b11	0645.40		nsf		r34	0705.18		b25		r55	0757.90		b25		b14	0835.09		nsf	
r47	0646.14		nsf		r51	0705.60		b25		r53	0757.96	20,06			b26	0835.10		nsf	
b13	0646.25		nsf		r56	0706.76		b25		r49	0758.14		b25		b12	0835.10		r52	
r40	0647.04		nsf		r55	0707.59		b25		r43	0758.43		b25		r50	0835.12	23,07		
b26	0647.07	12,14			b25	0708.40		r50		b25	0759.65		r50		r50	0836.21		nsf	
r46	0647.81		b15		r43	0708.43		b25		b16	0759.84		r37		r46	0836.93		b25	
b27	0648.62		r34		b16	0708.71		nsf		b11	0760.25		r37		r43	0837.64		b25	
b12	0649.81		r40		b12	0709.79		nsf		b12	0760.92		r37		r49	0837.73		b25	
r34	0650.46		nsf		r53	0709.87		b25		b25	0761.00	15,18			r51	0837.75		b25	
r51	0651.76		b15		r37	0711.20		b25		r37	0761.03		b25		r44	0838.35		b25	
r44	0652.03		b15		r48	0711.25		b25		r48	0761.39		b25		r54	0838.37		b25	
r52	0652.07		b15		r45	0711.67		b25		r45	0761.50		b25		r56	0838.90		b25	
b15	0652.31		nsf		r51	0712.57	20,05			r53	[illegible]		b25		b27	0839.25		r52	
b14	0652.37		r40		b27	0712.79		r34		r52	0763.21		b27		r55	0841.76		b25	
r49	0652.39		b15		b26	0713.43		r50		b14	0764.96		r37		b16	0842.79		r52	
r55	0652.79		nsf		r50	0716.18		b25		r47	0766.03		b25		b05	0842.87		nsf	
r56	0654.23		b15		r47	0716.20		b25		r50	0766.32		b25		r45	0842.89		b25	
r53	0655.07		nsf		r46	0717.53		b25		r46	0767.35		b25		r48	0843.17		b25	
b05	0655.18		r52		r51	0717.71		b25		r51	0767.85		b25		b26	0844.00	12,12		
b25	0655.87		r52		r54	0718.34		b25		r54	0768.48		b25		b27	0844.34	16,12		
b16	0655.92		r40		b27	0718.65	17,12			r44	0768.78		b25		r53	0844.68		b25	
r43	0656.06		b15	yes	b13	0718.81		nsf		b13	0768.82		r37	yes	r52	0845.00		b27	
r48	0656.45		nsf		r56	0718.87		b25		r56	0769.01		b25		b06	0846.93		r50	
r37	0656.48		nsf		r44	0718.95		b25		r49	0769.79		b25		r47	0847.42		b25	
b08	0656.59		nsf		r52	0719.15		nsf		r43	0770.01		b25		b17	0849.43		r52	
r45	0656.95		nsf		b17	0719.54		nsf		b25	0771.31		nsf		b13	0849.48		nsf	
b26	0659.79		r40		r55	0719.70		b25		b16	0771.42		nsf		b12	0852.01		r52	
r50	0661.39		nsf		r49	0719.93		b25		b11	0771.82		nsf		b11	0852.79		r52	
b17	0663.32		r40		b06	0720.28		r34	yes	b17	0773.54		nsf		r46	0853.84		b25	
r54	0663.54		nsf		r43	0720.46		b25		r55	0773.82		b25		b14	0854.17		r52	
r44	0664.23		nsf		b25	0720.51		r50		r48	0775.23		b25		b26	0854.18		nsf	
r52	0664.35		nsf		r53	0721.98		b25		r45	0775.26		b25		r43	0854.54		b25	
b11	0664.48		r40		r49	0722.90	nc			r53	0776.75		b25		r49	0854.71		b25	
r47	0665.21		b08	yes	r37	0723.23		b25		r52	0777.06		b27		r51	0854.73		b25	
r46	0665.32		nsf		r48	0723.35		b25		b06	0777.14		nsf		r44	0855.26		b25	
b13	0665.32		r40		r45	0723.70		b25		b12	0778.37		nsf		r54	0855.35		b25	
b25	0665.68	14,19			b27	0724.90		nsf		b14	0778.73		nsf		r56	0855.89		b25	
b27	0666.10		r34		b26	0725.54		r50		r47	0779.79		b25		b27	0856.23		nsf	
r40	0666.12		nsf		b16	0727.79		nsf		r50	0785.26		b25		r55	0858.75		b25	
b14	0667.48		r40	yes	r47	0728.23		b25		b27	0786.01		nsf		b16	0859.70		r52	
r52	0505.07	nc			r50	0728.29		b25		r46	0786.21		b25		r45	0859.79		b25	
r52	0521.93	22,04			b12	0728.87		nsf		r49	0786.78		b25		r48	0860.15		b25	
r51	0556.67	20,06			r46	0729.56		b25		r51	0786.79		b25		r53	0861.67		b25	
r49	0667.57		nsf		r51	0729.82		b25		r43	0786.92		b25		r52	0861.98		b27	
b12	0667.85		nsf		r54	0730.45		b25		r54	0787.42		b25		b06	0863.84		r50	
r34	0669.54		nsf		r44	0730.98		b25		r44	0787.64		b25		r47	0864.32		b25	
r51	0669.89		nsf		r56	0730.98		b25		b13	0787.68		nsf		b25	0864.75	16,18		
r56	0671.04		nsf		r55	0731.81		b25		r56	0787.95		b25		r52	0865.78	nc		
r55	0671.87		nsf		r49	0732.04		b25		b05	0789.84	12,15			b17	0866.34		r52	
b05	0671.92		r52		b06	0732.31		nsf		b26	0790.75		nsf		b13	0868.56		r52	

b12	0868.92		r52
b11	0869.70		r52
r46	0870.75		b25
b14	0871.07		r52
r43	0871.45		b25
r49	0871.70		b25
r51	0871.71		b25
r44	0872.17		b25
r54	0872.34		b25
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r56	1314.46		b25
b16	1316.17		r52
r45	1316.26		b25
r55	1317.32		b25
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r48	1318.73		b25
r53	1320.25		b25
r47	1320.79		b25
r51	1321.50	23,04	
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b13	1325.03		r52
b12	1325.39		r52
b11	1326.17		r52
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r46	1327.21		b25
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r43	1327.92		b25
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r56	1331.45		b25
b27	1332.75	15,10	
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r45	1333.17		b25
r49	1333.18	nc	
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r48	1335.71		b25
r53	1337.23		b25
r47	1337.70		b25
r52	1339.64		b25

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b13	1341.93		r52
b12	1342.29		r52
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r50	1343.95		naf
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r46	1344.12		b25
b14	1344.45		r52
r43	1344.82		b25
r44	1345.54		b25
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r56	1348.43		b25
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r45	1350.07		b25
r55	1351.29		b25
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r48	1352.70		b25
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r47	1354.60		b25
r52	1356.62		b25
b17	1356.62		r52
b26	1358.54		naf
b13	1358.84		r52
b12	1359.20		r52
r49	1359.65	nc	
b11	1359.98		r52
b27	1360.56		naf
b25	1360.96		naf
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b14	1361.35		r52
r43	1361.73		b25
r44	1362.45		b25
r49	1364.25		b25
r51	1364.26		b25
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r56	1365.42		b25
r38	1365.78	21,07	
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r45	1366.98		b25
r55	1368.25		b25
r49	1368.75	nc	
r48	1369.68		b25
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r47	1371.51		b25
r48	1372.09	20,06	
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r52	1373.60		b25
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r46	1377.93		b25
b14	1378.26		r52
r43	1378.64		b25
r44	1379.35		b25
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r56	1382.40		b25
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r54	1389.45	24,05	
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r52	1390.59		b25
b13	1392.65		r52
r49	1392.71	nc	
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r46	1394.84		b25
b14	1395.17		r52
r43	1395.54		b25
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r48	1403.65		b25
r53	1405.17		b25
r47	1405.32		b25

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r52	1407.57		b25
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r44	1413.17		b25
r42	1414.53	nc	
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r51	1415.21		b25
r54	1415.84		b25
r56	1416.37		b25
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r45	1417.70		b25
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r43	1496.98		b25
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r43	1615.32		b25
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r44	1616.04		b25
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r56	1637.17		b25
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r45	1637.48		b25
r52	1639.15	nc	
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r43	1649.14		b25
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r55	1657.01		b25	b17	1694.75		r52	b11	1731.92		r52	b06	1766.98		nsf
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r47	1658.92		b25	b05	1696.57		nsf	b06	1733.14	19,12		r43	1767.48		b25
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r50	1659.46		nsf	b11	1698.10		r52	b27	1733.87	16,10		r51	1771.89		b25
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r56	1671.14		b25	r48	1709.37		b25	r53	1744.85		b25	b12	1781.85		r52
r52	1671.17	nc		r47	1709.64		b25	b17	1745.46		r52	r50	1782.59		b06
b16	1671.20		r52	r55	1710.35	21,10		r52	1747.26		b25	b11	1782.64		r52
r45	1671.29		b25	r53	1710.89		b25	b13	1747.68		r52	r46	1783.68		b25
b27	1672.98		nsf	b17	1711.65		r52	b12	1748.04		r52	b14	1784.01		r52
r55	1674.00		b25	r50	1712.56		nsf	r50	1748.62		b06	r43	1784.39		b25
r48	1675.40		b25	r52	1713.29		b25	b11	1748.82		r52	r44	1785.10		b25
r47	1675.82		b25	b13	1713.87		r52	r46	1749.87		b25	r49	1788.85		b25
r53	1676.92		b25	r50	1713.95	22,09		b14	1750.20		r52	r51	1788.87		b25
b17	1677.84		r52	b12	1714.23		r52	r43	1750.57		b25	r54	1789.50		b25
r52	1679.32		b25	b11	1715.01		r52	b05	1751.09		nsf	b16	1789.54		r52
b13	1680.06		r52	r46	1716.06		b25	r44	1751.29		b25	r45	1789.64		b25
b12	1680.42		r52	b14	1716.39		r52	r49	1754.89		b25	r56	1790.03		b25
b11	1681.20		r52	r43	1716.76		b25	r51	1754.90		b25	b05	1790.14		nsf
r46	1682.25		b25	b25	1717.26		r50	r54	1755.53		b25	r55	1792.89		b25
b14	1682.57		r52	r44	1717.48		b25	b16	1755.73		r52	r47	1794.17		b25
r43	1682.95		b25	r49	1720.92		b25	r45	1755.82		b25	r48	1794.29		b25
r51	1682.98	22,05		r51	1720.93		b25	r56	1756.06		b25	b26	1795.09		r51
b25	1683.29		r50	r54	17[illegible].56		b25	r39	1757.28	22,06		r53	1795.81		b25
r44	1683.67		b25	b16	1721.92		r52	r38	1758.81	21,08		b17	1796.18		r52
r49	1686.95		b25	r45	1722.01		b25	r55	1758.92		b25	b25	1796.84		r50
r51	1686.96		b25	r56	1722.09		b25	r48	1760.32		b25	b05	1797.42	17,13	
r54	1687.59		b25	r55	1724.95		b25	r47	1760.35		b25	r52	1798.21		b25
b16	1688.10		r52	r35	1725.53	21,08		r53	1761.84		b25	b13	1798.40		r52
r56	1688.12		b25	r48	1726.35		b25	b17	1762.37		r52	b12	1798.76		r52
r45	1688.20		b25	r47	1726.54		b25	r52	1764.25		b25	b11	1799.54		r52
r52	1688.29	22,03		r53	1727.87		b25	r54	1764.43	nc		b00	1799.57		r06

Annex D4

SHORT-FORM PRINT-OUT OF 50 BLUE LIGHT TANK BATTLES

In all print-outs the R No. is the random number selected as the point from which the battle begins. For key to print-outs see "Format for Results" in App C.

```
R No. 11564072
Battle 1
r56  232 18,10      b31  0, 0 10
r54  376 23, 6      b31  0, 0 8
r38  486 23, 7      b04 14,16 2
b06  489 13,13      r37 23, 4 2
b07  494 10,16      r43 20, 7 1
b01  500 10,14      r34 17, 4 2
b04  506 14,16      r46 18,10 2
r36  507 20, 5      b13  3, 3 2
r39  509 23, 6      b09 15,14 2
r34  528 17, 4      b08 11,17 2
r33  535 17, 5      b16  1,11 4
b02  536  9,12      r37 23, 4 2
r41  610 20, 5      b14  5, 7 2
r42  637 23, 3      b16  1,11 2
r56  675 18,10      b31  0, 0 6
b05 1204 11,16      r37 22, 3 3
r35 1284 19, 6      b03 18,12 2
r40 1297 20, 3      b08 15,12 8,37
b6 r9 hit

R No.22107017
Battle 2
r49  174 23, 3      b31  0, 0 8
r49  603 23, 3      b31  0, 0 4
r42  672 23, 3      b03 15, 7 2
b04  674 14,15      r47 20, 9 1
r36  675 20, 5      b15  6,23 2
b10  694 13,15      r35 20, 7 2
b05  694 16,13      r34 17, 4 1
r37  694 23, 4      b09 12,12 2
b02  727 10,17      r38 23, 7 2
r35  735 20, 7      b17  2, 4 3
r41  788 20, 5      b03 16, 8 2
b06  796 14,15      r45 20, 8 1
b09  804 13,12      r47 20, 9 1
b15  810  6,23      r43 20, 7 2
r38  820 23, 7      b17  2, 4 2
b07  822 14,12      r40 21, 4 2
r33  830 17, 5      b14  5, 7 3
r39  831 23, 6      b03 15, 9 2
b08  844 19,20      r45 20, 8 2
r34  867 17, 5      b16  1,11 3
b9 r9 hit

R No. 14461170
Battle 3
r54  000 23, 6      b31  0, 0 8
r56  344 18,10      b31  0, 0 10
b02  590 10,16      r43 20, 7 1
r48  590 20, 8      b31  0, 0 8
r34  599 17, 4      b07 12,12 2
b04  604 14,15      r46 18,10 1
r41  620 20, 5      b09 14,15 2
b08  624 15,16      r36 20, 5 2
b06  628 14,16      r47 20, 9 2
r40  629 21, 4      b05 13,13 3
b09  634 15,15      r46 18,10 1
r38 650  23, 7      b03 14,15 2
r36  672 20, 5      b07 12,11 4
r42 1397 22, 2      b10 19,14 2
r35 1450 20, 7      b07 13,12 2
```

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r33 1514 17, 5      b03 21,11 3
b03 1516 21,11      r39 22, 5 1,07
r39 1646 23, 6      b07 13,14 2
b6 r9 hit

R No.00145341
Battle 4
r55  122 20, 9      b31  0, 0 10
r54  266 23, 6      b31  0, 0 8
b10  553 14,16      r44 21, 4 1
r42  559 23, 3      b16  1,11 2
b02  569 13,14      r43 20, 7 1
r34  579 17, 4      b09 14,15 2
b09  581 14,15      r45 20, 8 1
r39  599 23, 6      b15  6,23 3
b07  613 15,14      r45 20, 8 1
r55  620 20, 9      b31  0, 0 6
r41  630 20, 5      b16  1,11 3
r54  659 23, 6      b31  0, 0 4
r40 1020 21, 4      b04 15,15 2
r35 1135 20, 7      b03 14,16 3
r33 1189 17, 5      b03 15,15 2
r36 1287 20, 5      b01 14,14 2
r37 1527 22, 3      b05 16,12 3
r38 1658 21, 7      b06 18,12 1
b4 r10 hit

R No. 26025002
Battle 5
r56  248 18,10      b31  0, 0 10
r38  436 23, 7      b12  2, 4 2
b02  440  9,15      r40 21, 4 2
r34  440 17, 4      b05 13,16 2
b03  449 13,14      r33 17, 5 1
b07  464 10,17      r45 20, 8 2
r40  464 21, 4      b16  1,11 2
r33  467 17, 5      b04 12,16 2
b01  468  9,16      r47 20, 9 2
r35  471 20, 7      b17  2, 4 3
b08  476 14,18      r43 20, 7 2
r39  506 23, 6      b16  1,11 2
b04  509 13,15      r43 20, 7 1
b06  513 13,16      r45 20, 8 1
r36  543 20, 5      b13  3, 3 2
r42  625 23, 3      b16  1,11 2
r37  680 22, 4      b16  1,11 2
r41  713 20, 5      b13  3, 3 5
b7 r10 hit

R No.26720757
Battle 6
r56  006 18,10      b31  0, 0 10
r50  046 23, 7      b31  0, 0 8
r49  292 23, 3      b31  0, 0 8
r51  553 20, 7      b31  0, 0 8
b15  729  6,23      r44 21, 4 2
r51  735 20, 7      b31  0, 0 4
r35  739 20, 7      b03 15,17 2
r42  743 23, 3      b11  2, 5 3
b05  751 14,16      r47 20, 9 1
b02  756 14,17      r37 23, 4 2
r34  758 17, 4      b14  5, 7 2
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b08  763 12,18      r43 20, 7 2
b03  770 15,17      r45 20, 8 1
r37  783 23, 4      b01 15,10 2
b10  794 16,15      r46 18,10 1
r40  795 21, 4      b16  1,11 2
b07  805 12,14      r41 20, 5 2
r39  829 23, 6      b09 14,10 2
r36  867 20, 5      b12  2, 4 2
b7 r7 hit

R No. 01435630
Battle 7
r52  000 21, 4      b31  0, 0 8
r49  224 23, 3      b31  0, 0 8
r49  386 23, 3      b31  0, 0 4
b15  473  6,23      r47 20, 9 1
r42  487 23, 3      b04 12,16 2
b10  495 14,16      r43 20, 7 1
b05  504 14,13      r41 20, 5 2
b01  506  9,15      r46 18,10 1
b03  529 14,12      r36 20, 5 1
r37  533 23, 4      b11  2, 5 3
r35  540 20, 7      b04 13,17 2
r36  548 20, 5      b14  5, 7 4
b04  572 13,17      r38 23, 7 2
b6 r4 hit

R No.05226071
Battle 8
r52  356 21, 4      b31  0, 0 8
r34  609 17, 4      b14  5, 7 2
b15  615  6,23      r41 20, 5 2
r38  616 23, 7      b10 14,14 2
b09  624 15,16      r46 18,10 1
b10  633 14,14      r35 20, 7 2
b02  636 14,14      r36 20, 5 2
b05  639 13,13      r43 20, 7 1
r39  646 23, 6      b17  2, 4 3
r41  646 20, 5      b16  1,11 2
r42  656 23, 3      b08 17,16 2
b06  667 14,15      r33 17, 5 3
r35  668 20, 7      b03 16,14 3
b07  673 17,18      r47 20, 9 1
r40  681 21, 4      b01 12,18 2
b08  691 17,16      r43 20, 7 2
b03  702 16,14      r36 20, 5 1
r37  723 23, 4      b04 17,15 2
r36 1164 20, 5      b04 15,15 2
r33 1208 17, 5      b04 15,16 2
b9 r10 hit

R No. 2673225
Battle 9
r53  253 20, 5      b31  0, 0 8
r51  309 20, 7      b31  0, 0 8
r49  372 23, 3      b31  0, 0 8
r51  470 20, 7      b31  0, 0 4
r55  481 20, 9      b31  0, 0 10
r49  569 23, 3      b31  0, 0 4
b05  588 10,14      r44 21, 4 1
r37  590 23, 4      b14  5, 7 2
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```
b03  594 17,18      r47 20, 9 1
r35  606 20, 7      b06 14,13 1
b09  619 14,14      r40 21, 4 2
b06  626 14,13      r45 20, 8 1
r41  634 20, 5      b13  3, 3 2
r38  634 23, 7      b04 14, 7 2
r39  648 23, 6      b07 13,16 2
r36  749 20, 5      b11  2, 5 2
r42 1294 22, 3      b10 11,15 6
b01 1332 13,15      r33 17, 5 2
r33 1333 17, 5      b04 12,10 1
r40 1415 20, 3      b08 17,21 5
b5 r9 hit

R No. 15515324
Battle 10
r51  038 20, 7      b31  0, 0 8
r51  353 20, 7      b31  0, 0 4
r52  396 21, 4      b31  0, 0 8
r42  496 23, 3      b01 12,15 2
b01  498 12,15      r43 20, 7 1
b02  505  9,19      r47 20, 9 2
b10  522 14,15      r36 20, 5 2
r33  532 17, 5      b13  3, 3 3
b09 1154 15,13      r41 20, 5 2,04
r35 1603 20, 8      b04 15,10 2,08,06,05
b4 r3 hit

R No. 25412520
Battle 11
r51  293 20, 7      b31  0, 0 8
r33  602 17, 5      b04 13,13 1
b01  615 12,14      r40 21, 4 2
r38  621 23, 7      b16  1,11 2
b07  627 18,15      r45 20, 8 1
r35  637 20, 7      b09 16,15 2
b15  639  6,23      r47 20, 9 1
b08  645 13,13      r44 21, 4 2
r39  647 23, 6      b02 12,10 2
b06  647 17,18      r46 18,10 1
b09  657 16,15      r45 20, 8 1
r40  662 21, 4      b17  2, 4 2
b05  698  9,12      r34 17, 4 2
r41  705 20, 5      b11  2, 5 2
r37  705 23, 4      b16  1,11 3
b03  730 11,15      r46 18,10 2
b8 r7 hit

R No. 14773101
Battle 12
b07  627 13,15      r43 20, 7 1
r39  640 23, 6      b02 14,10 1
b01  664 11,14      r42 23, 3 2
r33  666 17, 5      b08 15,12 1
b04  859 14,16      r38 23, 7 2
b03  885 15,15      r42 23, 3 2
b15  897  6,23      r36 20, 5 2
b05  921 13,16      r41 20, 5 2
r38  936 23, 7      b09 18,15 1
r36  973 20, 5      b08 18,11 3
r35  982 20, 7      b06 17,11 2
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r42	1012	23, 3	b02	14,10	4
r41	1032	20, 5	b06	17,12	2
r37	1076	23, 4	bo6	17,12	2
r47	1119	20, 9	b06	17,11	2
r34	1509	16, 3	b02	17,12	2

b6 r10 hit

R No. 12372223
Battle 13

b05	498	13,14	r46	18,10	1
r37	514	23, 4	b08	13,15	2
b02	523	13,16	r43	20, 7	1
r34	528	17, 4	b12	2, 4	2
b04	535	14,18	r33	17, 5	2
b01	537	11,14	r45	20, 8	2
b03	542	14,16	r46	18,10	2
r36	542	20, 5	b11	2, 5	2
r33	552	17, 5	b14	5, 7	2
r35	596	20, 7	b10	12,19	2
b15	607	6,23	r44	21, 4	2
b07	622	11,16	r47	20, 9	1
b08	626	13,15	r41	20, 5	2
b06	637	16,12	r43	20, 7	1
b09	643	17,14	r45	20, 8	2
b10	648	13,19	r39	23, 6	3
r40	683	21, 4	b11	2, 5	2
r39	686	23, 6	b16	1,11	2
r41	708	20, 5	b13	3, 3	2
r38	799	23, 7	b12	2, 4	2

b11 r9 hit

R No. 01350421
Battle 14

r55	038	20, 9	b31	0, 0	10
r49	063	23, 3	b31	0, 0	8
454	444	23, 6	b31	0, 0	8
r37	571	23, 4	b08	13,16	2
b07	572	14,15	r44	21, 4	2
r34	589	17, 4	b04	17,13	2
b02	591	14,13	r42	23, 3	2
r39	596	23, 6	b10	14,16	2
b10	596	14,16	r46	18,10	1
b15	599	6,23	r47	20, 9	1
r42	610	23, 3	b16	1,11	3
b05	635	13,13	r41	20, 5	2
r41	675	20, 5	b06	16,17	2
r33	1385	17, 5	b01	15,12	1,08
r40	1477	22, 4	b08	17,15	2,38
b06	1543	17,12	r38	21,10	2,03
r35	1548	23, 9	b03	18,12	2

b6 r8 hit

R No. 11217751
Battle 15

r53	000	20, 5	b31	0, 0	8
r48	306	20, 8	b31	0, 0	8
r50	339	23, 7	b31	0, 0	8
r38	680	23, 7	b08	16,16	2
b15	687	6,23	r45	20, 8	2
r35	697	20, 7	b07	14,15	2
r33	703	17, 5	b03	14,15	2
b03	709	14,15	r47	20, 9	1
b06	718	14,15	r45	20, 8	1
r41	737	20, 5	b13	3, 3	2
b01	740	12,12	r42	23, 3	2
b09	764	15,12	r34	17, 4	1
r39	1284	23, 6	b08	18,13	2
r37	1231	23, 4	b07	20,15	2
r42	1331	23, 3	b10	15,15	6
r34	1437	16, 5	b02	15,12	2
r40	1523	22, 4	b08	20,12	2

b5 r9 hit

R No. 17270124
Battle 16

r54	253	23, 6	b31	0, 0	8
r52	460	21, 4	b31	0, 0	8
r56	699	18,10	b31	0, 0	10
b03	703	17,12	r34	17, 4	1
r34	730	17, 4	b15	6,23	3
b10	731	13,15	r44	21, 4	1
r35	734	20, 7	b16	1,11	2
r42	738	23, 3	b08	14,14	2
r37	765	23, 4	b17	2, 4	2
b02	785	13,16	r44	21, 4	1
r36	1356	20, 5	b04	15,13	2
r38	1377	23, 7	b06	18,13	5
r33	1423	1, 5	b06	18,13	2
b07	1432	18,14	r39	22, 7	1
b06	1446	18,13	r44	21, 4	1
r41	1555	20, 5	b09	9,14	3

b5 r8 hit

R No. 05221367
Battle 17

r48	100	20, 8	b31	0, 0	8
b06	705	11,14	r35	20, 7	2
b07	713	13,15	r43	20, 7	1
r38	715	23, 7	b03	15,10	2
r33	716	17, 5	b12	2, 4	2
r39	716	23, 6	b04	13, 9	2
b09	741	11,12	r46	18,10	2
r41	745	20, 5	b02	19,13	1
r36	755	20, 5	b17	2, 4	2
b10	819	15,15	r45	20, 8	2
r42	822	23, 3	b04	13,10	2
r35	841	20, 7	b15	6,23	2
r34	841	16, 3	b03	15, 9	2
b02	849	18,13	r45	20, 8	1
b15	898	6,23	r44	21, 4	3
r40	902	21, 4	b08	13,12	2
b05	911	12,15	r43	20, 7	3
r37	952	23, 4	b16	1,11	3
r47	992	20, 9	b08	12,12	1

b7 r11 hit

R No. 23523236
Battle 18

r48	000	20, 8	b31	0, 0	8
r51	411	20, 7	b31	0, 0	8
b03	592	14,14	r43	20, 7	1
r35	613	20, 7	b13	3, 3	2
b10	615	14,16	r46	18,10	1
b04	627	9,16	r45	20, 8	2
r42	630	23, 3	b09	18,12	2
b08	633	11,14	r39	23, 6	2
r40	636	21, 4	b05	16,18	2
b07	643	18,14	r38	23, 7	1
r39	661	23, 6	b02	11,11	2
r36	677	20, 5	b09	19,13	2
r34	1515	17, 4	b05	20,12	3
r38	1596	21, 5	b06	19,13	3
r37	1649	23, 3	b05	19,11	2
r33	1781	15, 9	b01	12,14	5

b5 r9 hit

R No. 23264306
Battle 19

r55	486	20, 9	b31	0, 0	10
b04	531	13,15	r47	20, 9	1
r38	550	23, 7	b08	13,14	2
r39	561	23, 6	b03	12,11	2
r35	562	20, 7	b06	15,15	1
b07	564	16,14	r43	20, 7	1
b01	564	9,19	r47	20, 9	1
b06	568	15,15	r46	18,10	2
b15	585	6,23	r33	17, 5	3
r36	586	20, 5	b16	1,11	3
b02	651	12,19	r44	21, 4	1
r34	665	17, 4	b14	5, 7	2
b08	673	12,14	r46	18,10	1
b05	675	13,20	r45	20, 8	1
r37	697	23, 4	b09	16,13	2
r40	730	21, 4	b03	14,10	1
r47	1150	20, 9	b09	19,11	2
r42	1189	23, 4	b10	20,14	2
b03	1227	16,12	r46	18,10	1

b9 r9 hit

R No. 03264325
Battle 20

r56	317	18,10	b31	0, 0	10
r56	492	18,10	b31	0, 0	6
r50	632	23, 7	b31	0, 0	8
b08	741	18,16	r43	20, 7	1
r40	741	21, 4	b07	17, 6	1
r35	774	20, 7	b02	16,10	1
b03	776	16,13	r46	18,10	2
r36	781	20, 5	b15	6,23	2
r34	818	17, 4	b13	3, 3	2
r52	1198	21, 4	b07	21, 4	12
r52	1211	21, 4	b07	21, 4	9
r52	1226	21, 4	b07	21, 4	6
r52	1253	21, 4	b07	21, 4	3
r52	1296	21, 4	b07	21, 4	0
r52	1313	21, 4	b07	22, 4	0
r37	1398	22, 2	b05	16,15	2
r42	1413	22, 2	b10	19,13	3
r38	1468	23, 7	b07	22, 4	1
r41	1507	21, 3	b11	2, 5	2

b2 r8 hit

R No. 13276404
Battle 21

b04	495	13,12	r47	20, 9	1
r36	500	20, 5	b07	16,13	1
r35	508	20, 7	b16	1,11	2

b03	518	12,12	r34	17, 4	1
r38	541	23, 7	b17	2, 4	2
b09	573	18,16	r45	20, 8	1
b01	593	11,13	r47	20, 9	1
r42	594	23, 3	b02	11,15	2
b10	606	17,15	r43	20, 7	1
r53	612	20, 5	b31	0, 0	8
b02	620	10,15	r41	20, 5	2
b07	629	17,12	r39	23, 6	1
r41	630	20, 5	b06	13,16	2
r39	630	23, 6	b11	2, 5	2
r33	644	17, 5	b08	12,16	4
b15	656	6,23	r43	20, 7	2
b08	665	13,15	r47	20, 9	1
r40	667	21, 4	b14	5, 7	2
r34	720	17, 4	b06	13,15	2
r37	768	23, 4	b13	3, 3	2

b9 r10 hit

R No. 15733300
Battle 22

r49	181	23, 3	b31	0, 0	8
r56	573	18,10	b31	0, 0	10
b05	701	15,15	r41	20, 5	2
r37	702	23, 4	b03	14,15	2
r55	704	20, 9	b31	0, 0	10
b15	712	6,23	r45	20, 8	1
r36	727	20, 5	b07	17,16	2
b08	733	14,18	r46	18,10	1
r40	736	21, 4	b09	18,14	2
r33	1422	17, 6	b01	15,16	3
r34	1426	17, 5	b04	15, 7	1
r39	1431	23, 6	b10	17,16	4, 42
r42	1532	23, 2	b10	16,16	5
r38	1586	23, 9	b06	19,15	2, 35
b03	1616	18,15	r35	19, 7	2

b4 r8 hit

R No. 20726514
Battle 23

r48	061	20, 8	b31	0, 0	8
r55	586	20, 9	b31	0, 0	10
b06	596	17,16	r35	20, 7	1
r38	607	23, 7	b05	13,15	2
r40	610	21, 4	b07	12,11	2
b01	615	7,16	r45	20, 8	1
r35	626	20, 7	b12	2, 4	2
r33	643	17, 5	b03	13,16	2
r36	648	20, 5	b16	1,11	2
b08	652	14,16	r46	18,10	3
b10	655	16,17	r37	23, 4	2
b03	656	13,16	r34	17, 4	3
r42	657	23, 3	b05	13,15	2
r34	1146	17, 4	b07	16,10	1

b5 r7 hit

R No. 22334424
Battle 24

r48	063	20, 8	b31	0, 0	8
r55	107	20, 9	b31	0, 0	10
b09	465	14,15	r47	20, 9	1
r42	480	23, 3	b11	2, 5	2
b07	486	9,16	r45	20, 8	1
r41	497	20, 5	b05	12,17	2
b04	497	14,15	r43	20, 7	1
r39	523	23, 6	b08	13,18	2
r36	529	20, 5	b15	6,23	2
b10	568	12,17	r46	18,10	1
b06	581	14,16	r33	17, 5	2
b03	586	10,14	r38	23, 7	2
b05	598	13,16	r35	20, 7	2
r33	599	17, 5	b02	16,11	1
b08	604	13,17	r47	20, 9	2
b01	612	14,14	r40	21, 4	2
r52	676	21, 4	b31	0, 0	8
r37	1161	23, 4	b02	16, 9	2
r35	1251	20, 7	b02	16, 8	2

b9 r7 hit

R No. 07326713
Battle 25

r48	016	20, 8	b31	0, 0	8
r48	026	20, 8	b31	0, 0	4
b10	615	13,18	r39	23, 6	2
r42	616	23, 3	b04	13,13	2
r38	632	23, 7	b09	14,15	2
b06	633	12,14	r34	17, 4	2
b03	640	12,14	r47	20, 9	1
r35	645	20, 7	b12	2, 4	3
b05	650	14,12	r44	21, 4	2
r37	657	23, 4	b08	14,15	2

b07	662	12,12	r36	20, 5	4
r39	670	23, 6	b14	5, 7	2
r51	753	20, 7	b31	0, 0	8
r53	814	20, 5	b31	0, 0	8
r41	1485	19, 3	b09	18,12	2
r34	1541	17, 4	b08	17,15	2
b08	1657	17,15	r40	22, 4	3
r36	1678	20, 5	b04	16,13	2
r33	1781	17, 5	b01	17,15	8

b6 r9 hit

R No. 40437632
Battle 26

b02	711	11,13	r46	18,10	1
r34	714	17, 4	b09	17,13	1
r41	722	20, 5	b07	11,14	2
b09	725	17,13	r39	23, 6	1
r40	739	21, 4	b17	2, 4	2
b03	745	18,13	r45	20, 8	1
r35	753	20, 7	b11	2, 5	2
b15	771	6,23	r44	21, 4	2
b10	777	17,21	r39	23, 6	2
r42	790	23, 3	b05	14,11	2
b08	792	16,18	r45	20, 8	2
r38	792	23, 7	b17	2, 4	2
b06	918	15,12	r46	18,10	1
r37	920	23, 4	b17	2, 4	5
r36	1002	20, 5	b16	1,11	2
r33	1022	17, 4	b11	2, 5	4
b07	1042	13,13	r39	23, 6	2
r39	1061	23, 6	b13	3, 3	2
b05	1086	15,12	r46	18,10	1

b9 r10 hit

R No. 26241652
Battle 27

r56	107	18,10	b31	0, 0	10
r53	600	20, 5	b31	0, 0	8
b06	628	14,16	r47	20, 9	1
r41	630	20, 5	b04	14,15	2
r33	644	17, 5	b10	14,11	3
b09	647	17,16	r43	20, 7	1
r36	651	20, 5	b02	10,14	2
b02	654	10,14	r46	18,10	2
r38	654	23, 7	b16	1,11	2
r39	661	23, 6	b17	2, 4	2
b04	663	14,15	r47	20, 9	1
r35	673	20, 7	b07	12,17	3
b03	678	15,15	r43	20, 7	1
b01	692	11,12	r34	17, 4	2
b15,	705	6,23	r46	18,10	1
r42	717	23, 3	b08	14,16	2
b10	756	15,12	r47	20, 9	1
r40	758	21, 4	b07	12,16	2
r37	789	23, 3	b14	5, 7	2
b05	802	14,16	r43	20, 7	1
b07	809	12,15	r46	18,10	1
b08	821	14,15	r47	20, 9	1

b11 r9 hit

R No. 06033057
Battle 28

b01	607	15,13	r46	18,10	1
r35	615	20, 7	b15	6,23	2
r33	b29	17, 5	b05	11,14	2
r38	637	23, 7	b09,	13, 7	2
b06	638	11,12	r47	20, 9	2
b03	641	16,14	r46	18,10	1
b04	650	15,13	r39	23, 6	2
r41	653	20, 5	b17	2, 4	2
r36	674	20, 5	b14	5, 7	2
b08	677	17,20	r45	20, 8	2
b10	684	17,18	r40	21, 4	3
r42	715	23, 3	b16	1,11	5
r40	731	21, 4	b17	2, 4	4
r37	987	23, 4	b07	17,15	3
r34	1092	17, 6	b02	17,14	1
r39	1100	22, 5	b09	16, 7	2

b6 r10 hit

R No. 16344357
Battle 29

r52	126	21, 4	b31	0, 0	8
b04	472	13,15	r47	20, 9	1
r33	491	17, 5	b08	13,17	2
b01	503	7,15	r41	20, 5	2
r41	507	20, 5	b07	13,16	2
r36	515	20, 5	b02	8,14	4
b09	516	12,15	r44	21, 4	3
r40	531	21, 4	b06	14,15	3

b3 r4 hit

R No. 23305644
Battle 30

r56 060 18,10	b31 0, 0 10
r53 340 20, 5	b31 0, 0 8
b04 574 18,18	r47 20, 9 1
r42 587 23, 3	b06 11,14 2
b08 599 12,13	r44 21, 4 1
b02 603 11,16	r46 18,10 1
b03 610 12,14	r36 20, 5 2
r40 614 21, 4	b11 2, 5 2
b10 619 11,15	r33 17, 5 2
b05 626 11,16	r41 20, 5 2
r37 638 23, 4	b07 12,10 3
b15 639 6,23	r38 23, 7 4
r33 640 17, 5	b06 11,14 2
b01 654 8,14	r47 20, 9 2
r35 682 20, 7	b13 3, 3 2
r34 716 17, 4	b17 2, 4 4
r41 1365 20, 5	b09 15,15 4
b07 1408 12,12	r39 22, 5 2
r39 1413 22, 5	b09 15,15 2
b06 1419 16,12	r38 20, 7 1

b10 r8 hit

R No.27335317
Battle 31

r51 000 20, 7	b31 0, 0 8
r53 069 20, 5	b31 0, 0 8
b09 478 16,16	r44 21, 4 1
r41 484 20, 5	b07 15,11 1
b03 507 13,17	r47 20, 9 2
b08 510 15,23	r35 20, 7 2
b15 520 6,23	r46 18,10 3
r40 525 21, 4	b14 5, 7 3
r39 535 23, 6	b17 2, 4 3
r35 547 20, 7	b05 12,22 3
r55 547 20, 9	b31 0, 0 10
r36 632 20, 5	b13 3, 3 2
r42 653 23, 3	b11 2, 5 2
r38 688 23, 7	b16 1,11 2
r34 791 17, 4	b11 2, 5 3
r37 838 23, 4	b16 1,11 5
b05 1017 15,20	r47 20, 9 2
b02 1103 16,15	r43 20, 7 1,44
r33 1290 17, 5	b07 19,10 1

b6 r10 hit

R No.10455747
Battle 32

r51 186 20, 7	b31 0, 0 8
r54 349 23, 6	b31 0, 0 8
r40 515 21, 4	b08 .14,14 2
b08 517 14,14	r45 20, 8 2
b04 524 12,17	r47 20, 9 1
r36 542 20, 5	b11 2, 5 2
r42 551 23, 3	b06 15,14 2
b10 554 19,17	r47 20, 9 1
r33 627 17, 5	b11 2, 5 2
r34 636 17, 4	b12 2, 4 2
r37 662 23, 4	b16 1,11 2
b09 671 12,14	r41 20, 5 2
r39 674 23, 6	b14 5, 7 2
r41 677 20, 5	b12 2, 4 2
r38 736 23, 7	b12 2, 4 8
r35 778 20, 7	b13 3, 3 2

b4 r10 hit

R No. 22332620
Battle 33

r52 149 21, 4	b31 0, 0 8
b10 642 12,20	r43 20, 7 1
r42 660 23, 3	b13 3, 3 2
b06 661 15,13	r36 20, 5 1
r35 674 20, 7	b08 15,15 2
r38 674 23, 7	b12 2, 4 2
b08 674 15,15	r41 20, 5 8
b09 679 16,16	r43 20, 7 1
b05 689 14,18	r44 21, 4 2
r33 698 17, 5	b11 2, 5 2
b01 706 11,17	r36 20, 5 2
r41 711 20, 5	b14 5, 7 2
b03 715 12,14	r45 20, 8 1
r37 716 23, 4	b04 15,17 2
b07 729 15,15	r43 20, 7 1
r39 757 23, 6	b14 5, 7 2
r40 791 21, 4	b11 2, 5 2

b8 r8 hit

R No.20347542
Battle 34

r54 060 23, 6	b31 0, 0 8
b06 506 11,13	r47 20, 9 1
r34 521 17, 4	b03 10,14 2
b02 522 14,13	r33 17, 5 1
b01 529 14,14	r45 20, 8 1
r33 537 17, 5	b08 13,22 2
b05 538 10,15	r35 20, 7 2
b10 538 16,18	r38 23, 7 2
r37 562 23, 4	b13 3, 3 2
r38 576 23, 7	b16 1,11 2
b08 599 13,21	r45 20, 8 1
b04 626 14,14	r43 20, 7 1
b03 630 12,14	r45 20, 8 1
b07 635 12,13	r42 23, 3 3
b09 635 14,14	r41 20, 5 2
b15 636 6,23	r40 21, 4 2
r40 666 21, 4	b12 2, 4 3
r47 740 20, 9	b16 1,11 2
r36 784 20, 5	b11 2, 5 2
r35 834 20, 7	b11 2, 5 2
r41 904 20, 5	b13 3, 3 2
r39 1001 22, 5	b13 3, 3 3

b11 r10 hit

R No.07215450
Battle 35

r50 000 23, 7	b31 0, 0 8
r50 022 23, 7	b31 0, 0 4
r50 091 23, 7	b31 0, 0 2
r55 250 20, 9	b31 0, 0 10
r56 406 18,10	b31 0, 0 10
r56 422 18,10	b31 0, 0 6
r51 426 20, 7	b31 0, 0 8
r42 595 23, 3	b03 17,13 2
b08 595 16,16	r47 20, 9 1
b10 599 13,15	r44 21, 4 1
b04 612 13,15	r43 20, 7 2
b03 615 16,12	r46 18,10 2
r36 619 20, 5	b09 14,15 2
b02 621 10,16	r45 20, 8 2
r35 643 20, 7	b06 18,14 1
r34 657 17, 4	b17 2, 4 4
b15 659 6,23	r33 17, 5 2
r33 752 17, 5	b14 5, 7 3
r38 793 23, 7	b16 1,11 2
r41 795 20, 5	b14 5, 7 2
r37 871 23, 4	b14 5, 7 4
r39 908 23, 7	b12 2, 4 4
r40 944 22, 3	b11 2, 5 2
b01 1243 17,14	r43 20, 7 1
b05 1299 17,12	r47 20, 9 1

b8 r10 hit

R No.22132305
Battle 36

r54 047 23, 6	b31 0, 0 8
r55 057 20, 9	b31 0, 0 10
r49 544 23, 3	b31 0, 0 8
b09 583 16,17	r43 20, 7 1
r40 607 21, 4	b05 16,15 2
b10 622 18,17	r44 21, 4 2
b02 622 7,18	r34 17, 4 2
r41 623 20, 5	b13 3, 3 2
b08 623 12,20	r39 23, 6 2
b01 631 7,13	r43 20, 7 2
b15 636 6,23	r35 20, 7 3
b05 658 16,15	r44 21, 4 1
r34 676 17, 4	b03 16,18 2
r42 681 23, 3	b06 11,11 3
r37 682 23, 4	b16 1,11 4
r33 723 17, 5	b04 14,15 2
r54 841 23, 6	b31 0, 0 4
r35 1224 20, 7	b07 19,16 1
b07 1303 20,15	r39 23, 5 2
r36 1401 20, 5	b04 19,15 4

b8 r8 hit

R No.20436661
Battle 37

r55 217 20, 9	b31 0, 0 10
b04 807 13,13	r41 20, 5 2
b03 808 17,14	r44 21, 4 1
r36 812 20, 5	b08 14,14 2
r35 817 20, 7	b10 15,12 1
b15 846 6,23	r37 23, 4 2
b07 846 15,13	r43 20, 7 2
r37 847 23, 4	b12 2, 4 5
r39 856 23, 6	b08 14,14 2
b09 876 15,12	r47 20, 9 1
r41 892 20, 5	b16 1,11 2
r40 906 21, 4	b13 3, 3 2
r34 1070 17, 6	b14 5, 7 2
r42 1159 23, 3	b11 2, 5 2
r33 1190 17, 5	b14 5, 7 2

b5 r9 hit

R No. 22540032
Battle 38

r52 222 21, 4	b31 0, 0 8
r49 346 23, 3	b31 0, 0 8
b02 532 11,15	r43 20, 7 2
r34 538 17, 4	b13 3, 3 2
b07 551 16,15	r33 17, 5 2
b08 559 14,15	r46 18,10 1
b15 563 6,23	r44 21, 4 2
b06 564 12,15	r43 20, 7 1
r36 568 20, 5	b09 10,12 2
r38 574 23, 7	b16 1,11 3
r39 575 23, 6	b05 16,17 2
b10 582 18,19	r46 18,10 1
r41 670 20, 5	b14 5, 7 3
r37 673 23, 4	b11 2, 5 3
r35 755 20, 7	b12 2, 4 2

b6 r7 hit

R No. 01431244
Battle 39

r52 283 21, 4	b31 0, 0 8
r56 478 18,10	b31 0, 0 10
b02 760 16,14	r41 20, 5 1
r41 769 20, 5	b03 16, 9 1
r34 779 17, 4	b06 17,14 2
b08 786 15,13	r33 17, 5 1
b01 791 15,13	r43 20, 7 1
r33 795 1, 5	b17 2, 4 2
r40 802 21, 4	b05 17, 8 2
r35 849 20, 7	b12 2, 4 2
r39 949 23, 6	b16 1,11 3
r37 1036 23, 4	b15 6,23 2
r36 1076 20, 5	b16 1,11 2,10

b3 r8 hit

R No. 13352733
Battle 40

r54 499 23, 6	b31 0, 0 8
r40 734 21, 4	b07 12, 8 1
b15 737 6,23	r46 18,10 2
r42 742 23, 3	b02 13,16 2
b10 758 13,19	r45 20, 8 1
b08 775 12,15	r46 18,10 1
r41 779 20, 5	b11 2, 5 2
r33 792 17, 5	b17 2, 4 2
b02 1415 16,18	r34 17, 4 3
r34 1482 17, 4	b03 20,13 1
r35 1523 20, 7	b06 21,14 2
r36 1537 20, 5	b04 20,11 2

b4 r7 hit

R No. 01031700
Battle 41

r54 441 23, 6	b31 0, 0 8
r54 508 23, 6	b31 0, 0 4
r37 573 23, 4	b15 6,23 2
b01 574 13,18	r45 20, 8 2
r33 584 17, 5	b05 13,13 2
b05 590 13,13	r34 17, 4 2
b04 597 12,14	r44 21, 4 2
b15 608 6,23	r39 23, 6 3
r36 616 20, 5	b17 2, 4 2
r40 627 21, 4	b16 1,11 3
b08 629 19,17	r43 20, 7 1
r42 1334 22, 4	b09 18,11 1
r34 1389 17, 4	b07 17,16 2
b07 1530 18,15	r39 21, 4 2
r38 1638 23, 4	b06 16,15 4

b6 r7 hit

R No. 07767143
Battle 42

r56 028 18,10	b31 0, 0 10
r51 435 20, 7	b31 0, 0 8
b02 629 13,15	r46 18,10 1
r42 644 23, 3	b17 2, 4 2
r33 649 17, 5	b09 12,10 2
r34 652 17, 4	b06 15,17 2
b05 653 13,16	r44 21, 4 1
r40 666 21, 4	b08 12,15 2
r41 666 20, 5	b15 6,23 2
b10 672 15,16	r47 20, 9 1
r37 690 23, 4	b07 16,14 2
r36 695 20, 5	b17 2, 4 2
b04 707 15,17	r43 20, 7 2
b01 891 13,12	r43 20, 7 1
r38 899 23, 7	b06 16,16 2
r39 979 23, 6	b07 17,12 3

b5 r9 hit

R No.01675516
Battle 43

r51 358 20, 7	b31 0, 0 8
r42 551 23, 3	b10 17,17 2
b08 553 16,17	r39 23, 6 2
b09 556 17,16	r47 20, 9 1
b07 557 14,14	r45 20, 8 1
r39 573 23, 6	b12 2, 4 2
b15 574 6,23	r46 18,10 2
r38 577 23, 7	b04 14, 8 1
r41 587 20, 5	b16 1,11 2
b05 594 11,15	r36 20, 5 2
b06 595 15,14	r45 20, 8 1
b10 598 17,16	r35 20, 7 4
r37 607 23, 4	b17 2, 4 2
r40 623 21, 4	b04 14, 7 2
b27 1531 18,12	r56 18,12 9
b27 1560 18,12	r56 18,12 2
b27 1585 18,12	r51 18,12 0
b27 1589 18,12	r56 18,12 0
r33 1623 17, 5	b01 15,13 1

b7 r7 hit

R No.17167071
Battle 44

r48 371 20, 8	b31 0, 0 8
r50 400 23, 7	b31 0, 0 8
b10 702 13,20	r46 18,10 1
r41 719 20, 5	b02 15,14 2
b09 737 14,14	r34 17, 4 2
r33 739 17, 5	b06 16, 7 1
b05 744 12,17	r42 23, 3 2
b01 744 13,15	r38 23, 7 2
r34 745 17, 4	b07 16,13 1
b02 764 16,15	r36 20, 5 4
r42 766 23, 3	b08 15,13 4
r37 782 23, 4	b17 2, 4 2
b15 789 6,23	r46 18,10 1
r38 840 23, 7	b14 5, 7 3
r35 1311 20, 7	b08 17,12 2

b6 r7 hit

R No.22743037
Battle 45

r56 177 18,10	b31 0, 0 10
r50 397 23, 7	b31 0, 0 8
r53 467 20, 5	b31 0, 0 8
r53 551 20, 5	b31 0, 0 4
r38 637 23, 7	b06 18,15 1
b06 639 18,15	r46 18,10 1
r33 653 17, 5	b14 5, 7 2
r34 664 17, 4	b16 1,11 2
b10 667 13,13	r45 20, 8 1
b01 683 12,14	r44 21, 4 3
r42 684 23, 3	b02 14,11 2
r36 1381 19, 5	b09 20,14 1
r37 1424 23, 4	b09 20,14 2,05,39

b3 r6 hit

R No.23537612
Battle 46

r56 296 18,10	b31 0, 0 10
b01 515 9,16	r46 18,10 2
r38 516 23, 7	b13 3, 3 2
b06 535 13,14	r45 20, 8 1
b04 545 13,18	r37 23, 4 2
r42 548 23, 3	b16 1,11 2
b08 551 15,22	r46 18,10 1
b10 552 11,13	r44 21, 4 2
b02 558 9,17	r33 17, 5 3
r33 560 17, 5	b09 18,15 2
r36 596 20, 5	b07 13,17 5
r40 596 21, 4	b12 2, 4 2
r37 1262 23, 4	b07 12,14 2
r35 1355 20, 7	b09 14,11 1
r39 1370 23, 6	b07 13,13 3

b6 r8 hit

R No.07236443
Battle 47

r48 435 20, 8	b31 0, 0 8
r39 544 23, 6	b04 12,14 2
r36 549 20, 5	b05 11,11 2
b10 555 12,15	r43 20, 7 2
b04 562 12,14	r44 21, 4 2
b07 564 11,14	r33 17, 5 2
b02 565 13,20	r46 18,10 2
b01 571 10,17	r37 23, 4 2
r33 573 17, 5	b11 2, 5 2
r34 592 17, 4	b08 13,16 3
r37 599 23, 4	b14 5, 7 4
b09 745 17,15	r47 20, 9 1

b08 752 12,15	r44 21, 4 1	r36 636 20, 5	b16 1,11 3	b05 444 9,18	r47 20,9 1	b05 558 8,14	r35 20, 7 2
b03 778 16,17	r45 20, 8 1	r40 649 21, 4	b10 14,16 2	b02 446 10,18	r33 17,5 2	r37 566 23, 4	b02 14,11 2
r35 796 20, 7	b05 12,10 1	b07 650 17,13	r44 21, 4 2	r40 450 21, 4	b17 2,4 2	b10 570 18,18	r47 20, 9 1
r40 874 21, 4	b05 12,10 4	b06 666 16,13	r46 18,10 2	r35 458 20, 7	b13 3,3 2	r38 583 23, 7	b06 13,14 2
r42 920 23, 3	b05 12,11 2	b04 674 13,13	r45 20, 8 1	r52 460 21, 4	b31 0,0 8	r41 588 20, 5	b12 2, 4 2
b05 1015 12,12	r46 18,10 2	r33 684 17, 5	b16 1,11 2	b07 •465 10,16	r45 20,8 1	b15 607 6,23	r40 21, 4 3
r38 1283 22, 7	b06 13,15 8	r47 1019 20, 9	b05 14,17 2	b08 469 9,19	r41 20,5 3	b06 614 13,14	r39 23, 6 2
b9 r9 hit		r34 1026 17, 4	b01 11,11 1	r41 547 20, 5	b12 2,4 2	b02 654 15,12	r44 21, 4 1
		r37 1089 23, 4	b05 14,17 3	r33 568 17, 5	b13 3,3 2	r39 670 23, 6	b13 3, 3 3
		r42 1331 22, 3	b10 17,13 2	r42 581 23, 3	b11 2,5 4	r50 682 23, 7	b31 0, 0 8
R No.12207646		b6 r10 hit		r36 591 20, 5	b14 5,7 2	r36 687 20, 5	b14 5, 7 3
Battle 48				r34 632 17, 4	b11 2,5 2,47,37	r33 692 17, 5	b16 1,11 3
r53 098 20, 5	b31 0, 0 8			b10 1753 16,12	r37 22,2 2	r35 723 20, 7	b11 2, 5 5
b08 581 13,15	r47 20, 9 1	R No.11617242		b7 r8 hit		b04 877 15,15	r46 18,10 1
r35 591 20, 7	b09 18,16 1	Battle 49				r40 923 21, 4	b07 15,16 2
b03 612 15,15	r47 20, 9 1	r53 266 20, 5	b31 0, 0 8			r47 958 20, 9	b03 13,12 1
r39 613 23, 6	b14 5, 7 2	b03 414 16,15	r44 21, 4 1	R No.12312073		b6 r10 hit	
r38 614 23, 7	b06 16,13 1	r37 437 23, 6	b09 17,18 2	Battle 50			
b15 628 6,23	r33 17, 5 2	b15 444 6,23	r43 20, 7 2	r34 557 17, 4	b09 15,12 2		

Annex D5

SHORT-FORM PRINT-OUT OF 14 BLUE HEAVY TANK BATTLES

In all print-outs the R No. is the random number selected as the point from which the battle begins. For key to print-outs see "Format for Results" in App C.

```
R No. 11234436
Battle 1
r48  079 20, 8     b31  0, 0 8
r51  386 20, 7     b31  0, 0 8
b10  941 14,15     r47 20, 9 1
b06  958 14,14     r43 20, 7 1
b09  972 14,15     r47 20, 9 1
r42  973 23, 3     b12  2, 4 2
b02  981 12,19     r46 18,10 1
r38  985 23, 7     b13  3, 3 2
b03  985 14,13     r34 17, 4 1
r35 1008 20, 7     b16  1,11 2
r34 1033 17, 4     b12  2, 4 2
r36 1261 20, 5     b08 14,11 1
r39 1309 23, 6     b01 13,20 2
r33 1345 17, 5     b07 17,15 2
r40 1385 20, 3     b04 12,15 2
b5 r8 hit

R No. 07510552
Battle 2
r56  107 18,10     b31  0, 0 10
r51  171 20, 7     b31  0, 0 8
r52  424 21, 4     b31  0, 0 8
b04  950 14,15     r45 20, 8 1
b08  957 10,14     r46 18,10 1
b09  960 14,14     r47 20, 9 1
b02  967  9,16     r43 20, 7 1
r41  978 20, 5     b17  2, 4 2
r34  979 17, 4     b16  1,11 2
r40  999 21, 4     b06 15, 7 2
r36 1003 20, 5     b07 14,16 3
r38 1045 23, 7     b16  1,11 2
r35 1410 20, 7     b06 16, 7 1
r42 1456 22, 2     b10 19,22 2
r37 1561 22, 3     b05 13,18 2
r33 1586 17, 5     b06 17, 6 1
b4 r9 hit

R No. 02512271
Battle 3
r52  245 21, 4     b31  0, 0 8
r51  321 20, 7     b31  0, 0 8
r56  755 18,10     b31  0, 0 10
b07  961 13,15     r46 18,10 1
b05  977 12,15     r35 20, 7 2
r37  977 23, 4     b16  1,11 2
r39  981 23, 6     b15  6,23 2
b06  989 12,15     r41 20, 5 2
b01  996  9,15     r47 20, 9 2
b15  998  6,23     r42 23, 3 2
r38 1016 23, 7     b17  2, 4 2
r33 1017 17, 5     b11  2, 5 2
b08 1033 15,20     r36 20, 5 2
r35 1192 20, 7     b04 17,14 2
r42 1210 23, 3     b03 13,16 2
b04 1223 17,14     r36 20, 5 1
r36 1228 20, 5     b09 12,15 3
r34 1272 16, 4     b10 14,15 2
r41 1342 20, 4     b03 13,15 2
b7 r9 hit

R No. 17360630
Battle 4
r55  000 20, 9     b31  0, 0 10
r54  120 23, 6     b31  0, 0 8
r48  172 20, 8     b31  0, 0 8
r53  505 20, 5     b31  0, 0 8
r49  606 23, 3     b31  0, 0 8
b06  960 12,15     r47 20, 9 1
b04  964 13,16     r46 18,10 1
r37  979 23, 4     b14  5, 7 2
b08 1000 12,20     r43 20, 7 2
b03 1005 16,15     r46 18,10 1
r38 1011 23, 7     b16  1,11 3
b07 1030 14,15     r47 20, 9 1
r53 1035 20, 5     b31  0, 0 4
r40 1038 21, 4     b14  5, 7 2
r35 1056 20, 7     b13  3, 3 2
r39 1075 23, 6     b16  1,11 2
r34 1076 17, 4     b09 14,11 1
r36 1082 20, 5     b15  6,23 2
r33 1165 16, 5     b02 15,16 2
r42 1227 23, 3     b09 15,12 2
r41 1344 20, 4     b09 16,12 2
b5 r10 hit

R No. 14763706
Battle 5
r53  377 20, 5     b31  0, 0 8
r48  569 20, 8     b31  0, 0 8
b02  956  9,15     r43 20, 7 1
b08  962 14,21     r47 20, 9 1
r41  984 20, 5     b13  3, 3 2
b09  988 13,15     r43 20, 7 1
r38 1007 23, 7     b16  1,11 3
b07 1018 10,14     r45 20, 8 3
r47 1033 20, 9     b15  6,23 2
b15 1040  6,23     r35 20, 7 2
r40 1041 21, 4     b13  3, 3 2
b06 1055 16,18     r46 18,10 1
r39 1067 23, 6     b17  2, 4 2
r34 1080 17, 4     b12  2, 4 2
r33 1138 17, 5     b04 14,16 2
r42 1430 23, 3     b10 15,15 2
r35 1486 20, 7     b04 15,15 2
r36 1677 17, 5     b04 17,14 6
r37 1691 22, 2     b05 13,15 3
b6 r11 hit

R No. 24643405
Battle 6
r56  000 18,10     b31  0, 0 10
r55  199 20, 9     b31  0, 0 10
b15  947  6,23     r46 18,10 1
r38  971 23, 7     b17  2, 4 2
r39  979 23, 6     b12  2, 4 2
b03  985 11,20     r33 17, 5 2
r33  992 17, 5     b14  5, 7 2
b06  996 16,17     r47 20, 9 1
b02 1019 10,13     r46 18,10 1
r34 1019 17, 4     b16  1,11 3
r35 1051 20, 7     b14  5, 7 2
r37 1076 23, 4     b09 14,15 2
r42 1112 23, 3     b10 14,14 2
r40 1401 21, 4     b08 12,15 2
r36 1502 22, 3     b04 14,14 2
r41 1533 19, 3     b09 15,14 3
b4 r10 hit

R No. 00511446
Battle 7
r53  082 20, 5     b31  0, 0 8
r53  277 20, 5     b31  0, 0 4
r54  755 23, 6     b31  0, 0 8
r52  787 21, 4     b31  0, 0 8
r49  870 23, 3     b31  0, 0 8
r37  972 23, 4     b13  3, 3 2
b05  974 13,18     r33 17, 5 2
b02  979 12,18     r35 20, 7 2
r34  983 17, 4     b11  2, 5 2
b10 1011 15,17     r47 20, 9 1
r42 1014 23, 3     b17  2, 4 3
r53 1067 20, 5     b31  0, 0 2
b01 1085 12,15     r35 20, 7 2
r33 1104 17, 5     b15  6,23 2
r39 1109 23, 6     b09 14,15 2
r38 1129 23, 7     b06 13,15 2
r40 1132 21, 4     b07 14,14 3
r35 1137 20, 7     b13  3, 3 2
r41 1174 20, 5     b15  6,23 2
b4 r9 hit

R No. 24521727
Battle 8
r53  171 20, 5     b31  0, 0 8
r53  414 20, 5     b31  0, 0 4
r51  648 20, 7     b31  0, 0 8
r54  682 23, 6     b31  0, 0 8
b09  959 12,15     r45 20, 8 1
b05  966  9,17     r47 20, 9 1
r34  980 17, 4     b12  2, 4 2
b02  988 12,14     r46 18,10 1
r41 1027 20, 5     b13  3, 3 2
r42 1100 23, 3     b03 14,15 2
r33 1109 17, 5     b04 15,11 1
r39 1116 23, 6     b07 16,12 1
r40 1139 21, 4     b04 15,11 1
r36 1267 20, 5     b04 15,12 2
r38 1323 24, 8     b06 16,15 2
r35 1359 20, 7     b07 15,13 2
b3 r9 hit

R No. 03653466
Battle 9
r49  567 23, 3     b31  0, 0 8
r49  610 23, 3     b31  0, 0 4
b04  957 15,17     r46 18,10 1
b07  967 13,12     r45 20, 8 1
b06  970 11,16     r47 20, 9 2
r49  977 23, 3     b31  0, 0 2
r36  978 20, 5     b17  2, 4 2
b10 1006 16,17     r47 20, 9 1
r39 1010 23, 6     b12  2, 4 3
r35 1020 20, 7     b11  2, 5 3
r41 1031 20, 5     b14  5, 7 2
r38 1061 23, 7     b16  1,11 2
b03 1061 15,15     r37 23, 4 2
b09 1069 13,13     r44 21, 4 3
r34 1074 17, 4     b15  6,23 2
r33 1097 17, 5     b13  3, 3 2
r40 1176 22, 3     b17  2, 4 2
r37 1196 23, 4     b11  2, 5 2
b02 1284 12,12     r44 21, 4 2
b01 1569 14,12     r43 20, 7 1
b8 r9 hit

R No. 04142163
Battle 10
r54  752 23, 6     b31  0, 0 8
r55  800 20, 9     b31  0, 0 10
r50  859 23, 7     b31  0, 0 8
b08  939 14,19     r46 18,10 1
r36  970 20, 5     b17  2, 4 2
b09  976 12,14     r37 23, 4 2
r38  982 23, 7     b15  6,23 2
b04  986 12,13     r42 23, 3 2
b15  989  6,23     r33 17, 5 2
r34 1003 17, 4     b13  3, 3 2
b02 1014 10,14     r41 20, 5 2
r41 1016 20, 5     b16  1,11 2
b06 1031 14,16     r46 18,10 1
r42 1151 23, 3     b07 16,11 2
r37 1167 23, 4     b05 14,16 3
b6 r6 hit

R No. 02127242
Battle 11
r56  081 18,10     b31  0, 0 10
r55  179h20, 9     b31  0, 0 10
r54  245 23, 6     b31  0, 0 8
r49  676 23, 3     b31  0, 0 8
b05  956  8,12     r45 20, 8 1
b02  969 13,12     r34 17, 4 1
b09  976 15,17     r41 20, 5 2
r37  978 23, 4     b17  2, 4 2
b04  985 14,14     r46 18,10 2
b01  989 13,15     r38 23, 7 2
r36  989 20, 5     b16  1,11 2
r41  996 20, 5     b13  3, 3 2
r34  996 17, 4     b03 13,11 1
b10  999 14,20     r44 21, 4 1
r42 1031 23, 3     b11  2, 5 2
r33 1064 17, 5     b13  3, 3 2
b07 1624 12,12     r39 22, 6 2
r38 1625 22, 8     b06 18,15 1
b08 1651 12,15     r40 20, 3 2
r35 1784 21, 9     b03 17,12 3
b8 r8 hit

R No. 14755534
Battle 12
r55  232 20, 9     b31  0, 0 10
r48  274 20, 8     b31  0, 0 8
r52  802 21, 4     b31  0, 0 8
b03  953 13,14     r46 18,10 1
b01  963 15,15     r43 20, 7 1
r40  983 21, 4     b12  2, 4 2
r34  988 17, 4     b14  5, 7 2
r33  991 17, 5     b13  3, 3 2
b02  998 11,13     r36 20, 5 2
r35 1002 20, 7     b17  2, 4 2
b10 1018 16,14     r46 18,10 2
b05 1023 14,14     r43 20, 7 2
r37 1025 23, 4     b16  1,11 2
b08 1036 13,19     r45 20, 8 2
r42 1042 23, 3     b04 14,14 2
r41 1045 20, 5     b06 15, 9 1
r38 1054 23, 7     b13  3, 3 2
r36 1474 20, 5     b06 17, 9 1
b6 r9 hit

R No. 01234567
Battle 13
r51  066 20, 7     b31  0, 0 8
b09  719 10,17     r43 20, 7 2
r41  730 20, 5     b17  2, 4 2
r36  732 20, 5     b01 12,16 4
b05  735  9,18     r46 18,10 2
r38  736 23, 7     b06 13,20 2
r37  739 23, 4     b14  5, 7 2
b04  752 12,14     r33 17, 5 2
b06  753 13,20     r47 20, 9 3
r35  768 20, 7     b11  2, 5 2
r34  846 17, 4     b13  3, 3 2
r40  937 21, 4     b16  1,11 2
r42 1003 23, 3     b16  1,11 2
r39 1099 21, 7     b15  6,23 2
b4 r9 hit

R No. 00233715
Battle 14
r54  000 23, 6     b31  0, 0 8
r49  607 23, 3     b31  0, 0 8
r54  654 23, 6     b31  0, 0 4
r49  702 23, 3     b31  0, 0 4
b02  957  9,14     r43 20, 7 1
b10  963 14,15     r45 20, 8 1
r34  976 17, 4     b14  5, 7 2
r37  977 23, 4     b11  2, 5 2
r41  978 20, 5     b13  3, 3 2
r39  978 23, 6     b15  6,23 2
b09  994 18,14     r43 20, 7 1
b07 1001 12,15     r47 20, 9 2
r40 1028 21, 4     b01 13,17 2
b05 1033 12,15     r46 18,10 2
r35 1074 20, 7     b04 12,14 3
r33 1123 17, 5     b06 15,19 2
r38 1508 23, 8     b06 14,17 2
b01 1632 14,15     r46 18,10 1
b6 r8 hit
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